SEPTEMBER-OCTOBER 1960

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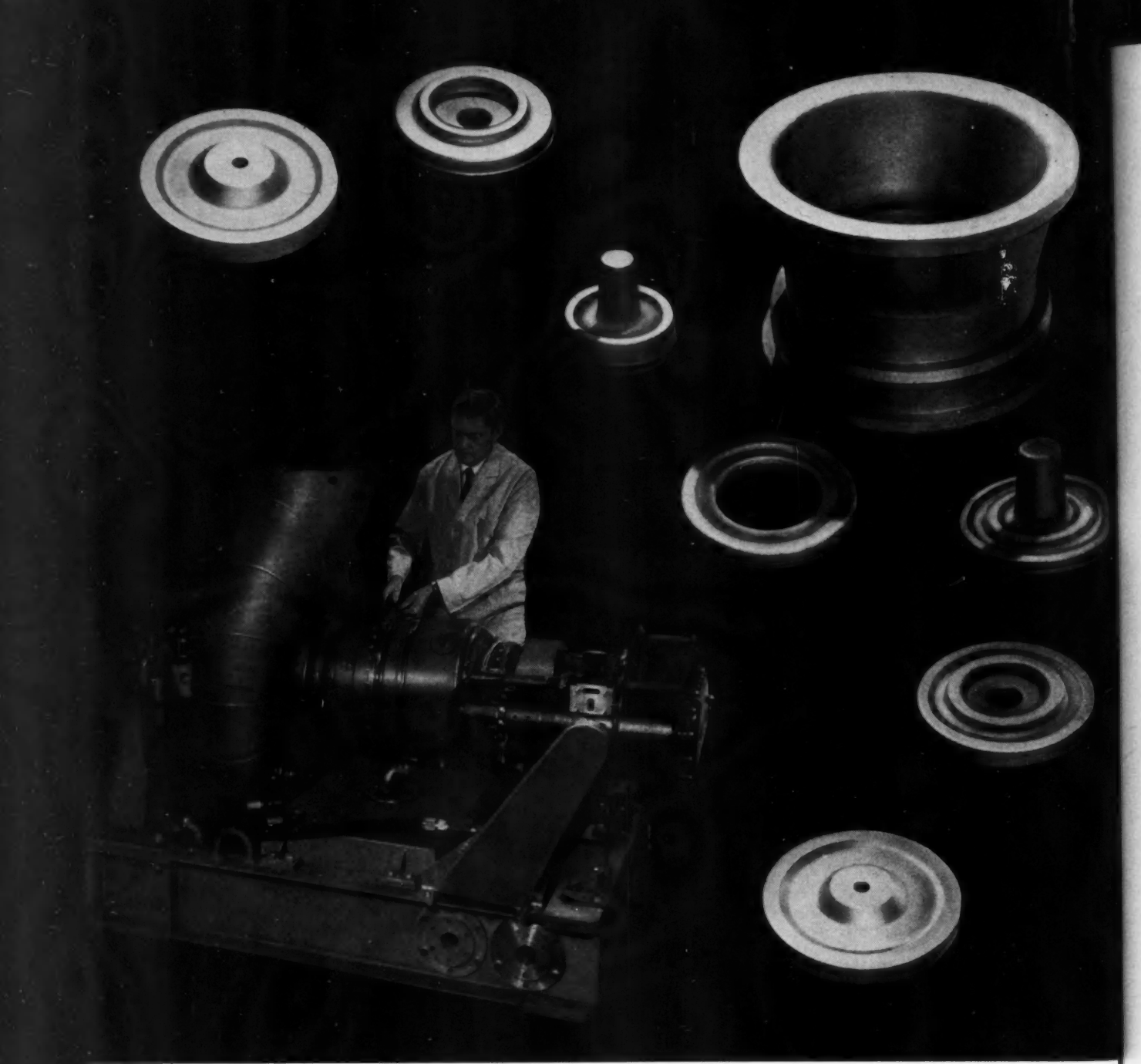

CAMERON FORGINGS IN THE SOLAR SATURN* ENGINE

Solar Aircraft Company's 1,100 H.P. Saturn Industrial Gas Turbine Engine weighs about 1,000 pounds—its unusually efficient performance is setting new standards in new applications for the up and coming gas turbines. Increased reliability and versatility in gas turbines required something new in forging performance. That's why Solar called on Cameron for all the rotating forgings in the Saturn.

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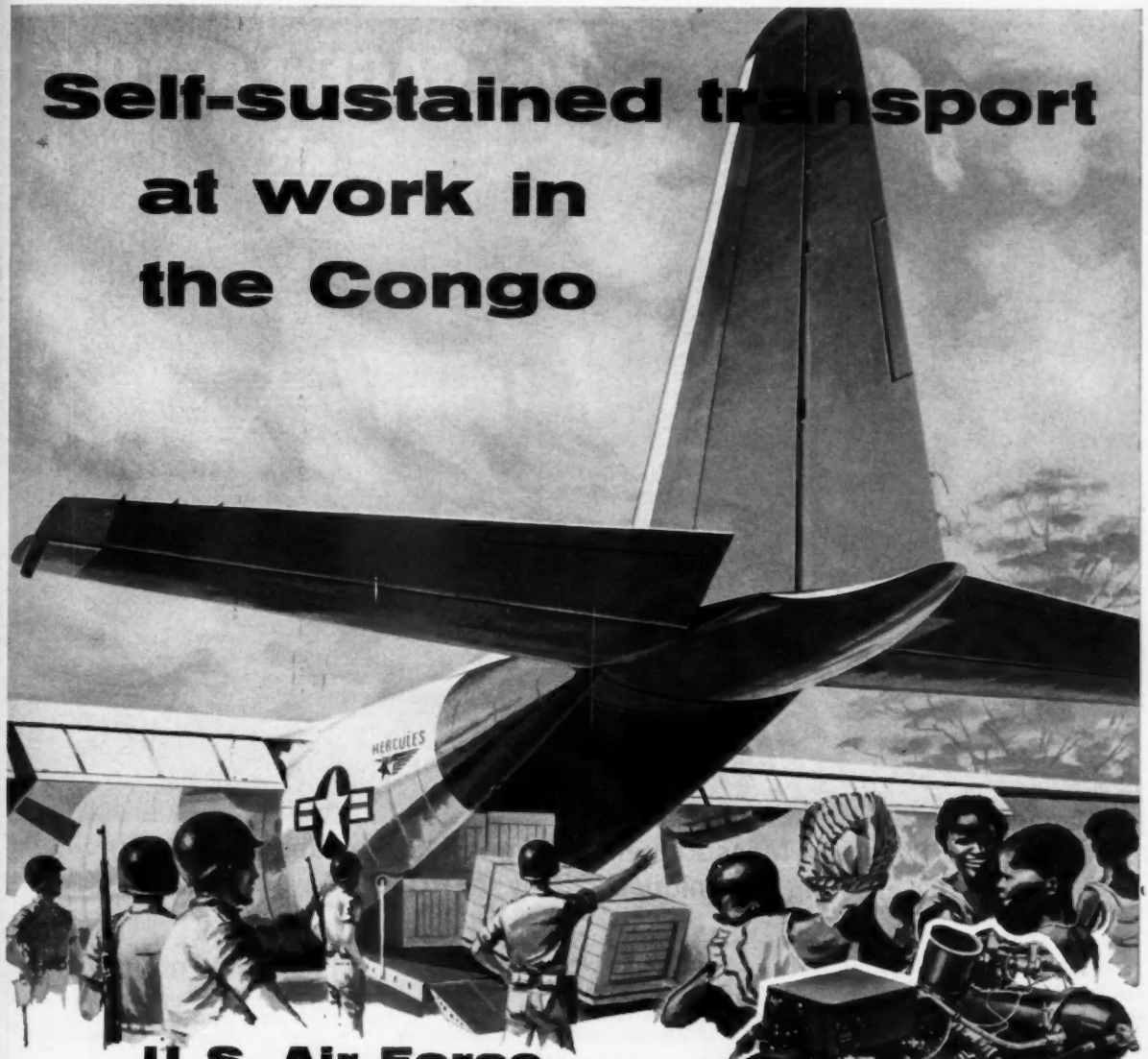
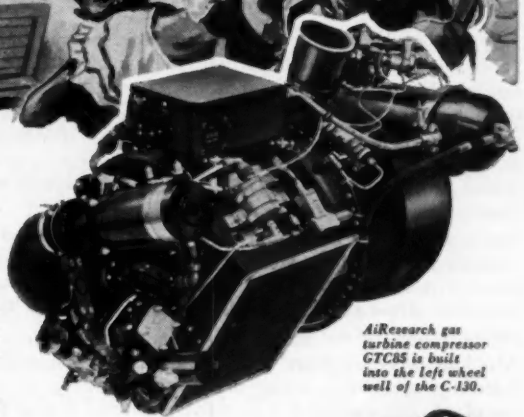
Self-sustained transport at work in the Congo



U. S. Air Force Lockheed C-130 Hercules

The recent crisis in the Congo has once again proved that the self-sustained aircraft is of vital importance in transporting cargo and passengers to and from landing fields where no ground support equipment exists.

The USAF Lockheed C-130 Hercules is designed to land and take off from extremely short runways carrying heavy loads of cargo or passengers. Equipped with an AiResearch gas turbine and starting system, the C-130 is entirely self-sufficient and can operate from the heat of the Congo to the cold of the Antarctic without the need of ground support equipment.



AiResearch gas turbine compressor GTC85 is built into the left wheel well of the C-130.

AiResearch air turbine starter ATS100 is installed on each of C-130's four turboprop engines.

Please direct inquiries to Phoenix Division.

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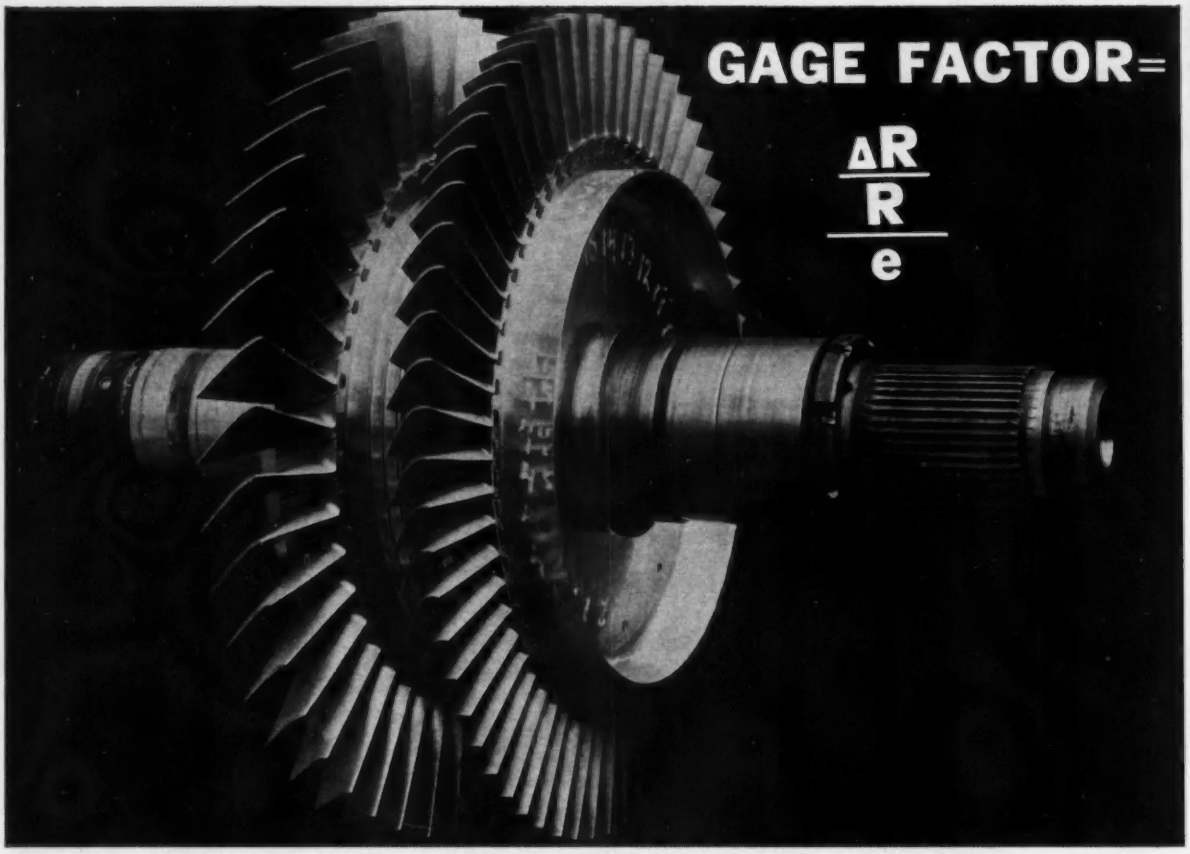

Vibratory Measurements Through Strain Gage Testing Techniques . . . by AEROTEST

Purpose of Vibratory Measurements: Forces that result from vibratory motion may be of sufficient magnitude to limit the use of an object or produce rapid failures. Some explicit objects affected by vibratory stresses and forces are bearings, shafts, compressors, turbines and stator vanes.

One of the primary causes of vibratory forces in rotating machinery is unbalance which is the result of a rotating body not being completely symmetrical in mass or geometry. When rotating, the displaced mass creates a centrifugal force which is repetitive and equal in frequency to its rotating speed.

When a stress or a strain (the two are interchangeable) occurs in a member which is vibrating, the resulting vibratory stress introduces a critical type of loading which, if not monitored, can result in a very costly test article failure. Knowledge of the extent of the vibrating stress enables AEROTEST to determine the usable life of a vibrating body before fatigue failure occurs.

Method of Operation: In order to measure the strain of rotative blades, discs or shafts, resistance of a bonded group of wires is accurately measured through amplification by the use of a bridge circuit. The sensitivity (known as gage factor) of the strain gage is defined as the change in a certain resistance for a given strain, or,

$$G.F. = \frac{\frac{\Delta R}{R}}{e}$$

ΔR = change in resistance of gage

R = original resistance of gage

e = strain in material causing gage to change resistance by ΔR

AEROTEST utilizes this strain gage testing technique when making vibratory measurements. Other parameters may also be placed under operating surveillance in its Gas Dynamics Laboratory, including: blade flutter, tip clearance and over-all linear motion and frequency. Complete AEROTEST facilities are described in a new brochure. Write today for your copy.

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GAS TURBINE

VOUME 1, No. 5, September-October, 1960

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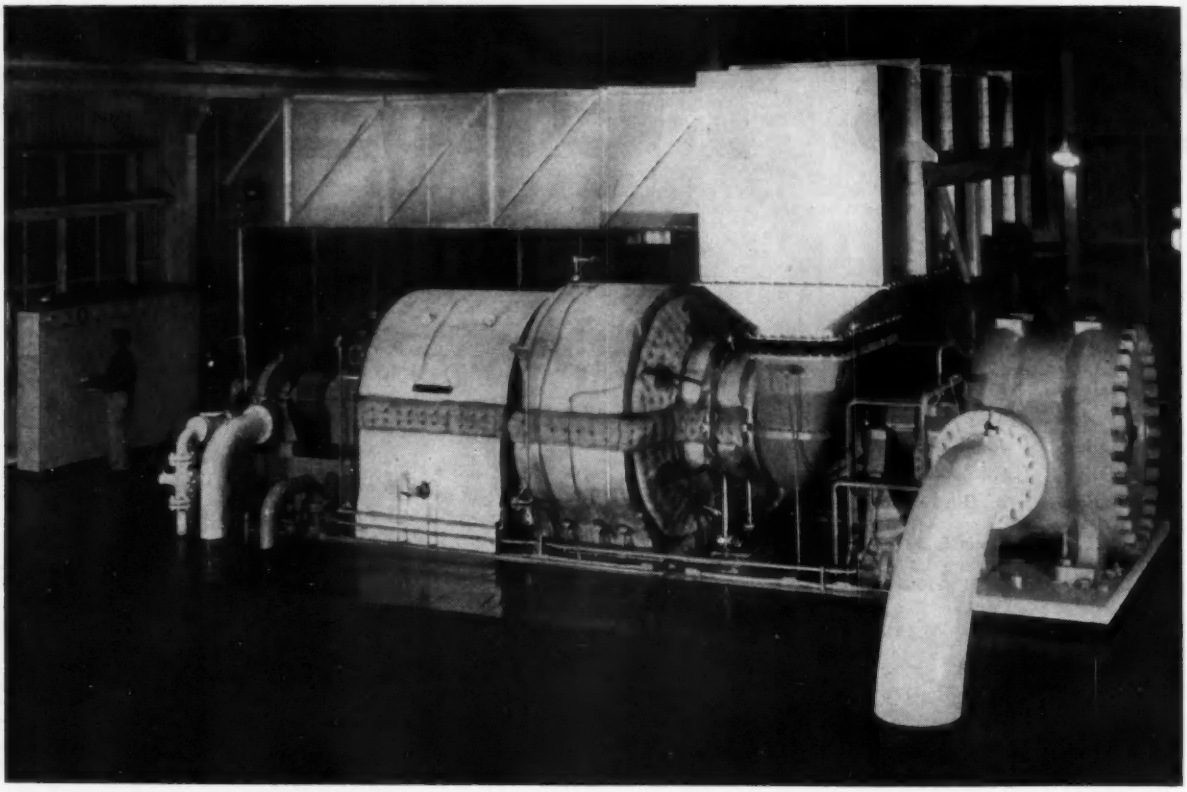

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Let us prove that Westinghouse gas turbines are the best way to raise transmission efficiency while lowering operating costs. Call your Westinghouse representative or write Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pa.

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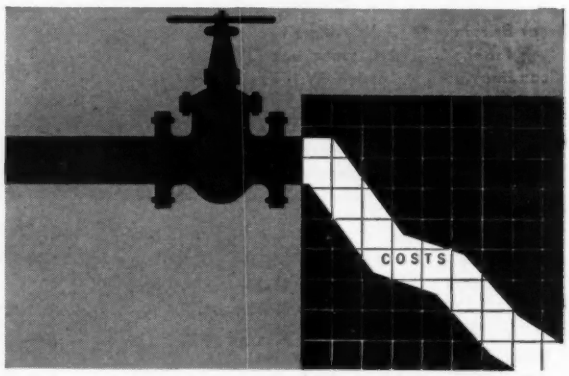

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GT EDITORIALLY SPEAKING

For Many—A Time for Decision

There is a big difference between building piston and gas turbine engines. The engine manufacturer is faced with one major question—when should he go into the gas turbine business to actually compete with the Diesel. Many straws in the wind help him plot his direction. For example, August 3, 1960 will long be remembered as the day over 20 engine manufacturers met at the Pentagon to review a gas turbine development specification for one 600-hp unit. This is the first specification that required the gas turbine to meet the fuel consumption and cost of the diesel. Those at the Pentagon may be divided into 3 groups. Allison, General Electric, Pratt & Whitney and Westinghouse have built piston engines in the past; today the only internal combustion engine they build is the gas turbine; AiResearch, Boeing, Orenda, Solar and Williams Research are of a new generation, their complete faith is in the gas turbine only. Most of the others that met on August 3rd build both piston engines and gas turbines. In these three groups only a few have seriously tried to compete with the diesel. Most gas turbines built today supplement the diesel—they do *not* compete with the diesel. The last group in particular, those building both piston and gas turbines, must decide whether or not to compete with themselves—to make the gas turbine actually compete with the diesel in cost and fuel consumption. It's time for decision—this competition will become more intense as the gas turbine further demonstrates its effectiveness.

R. Tom Sawyer

Opinions expressed do not imply Department of Defense endorsement of factual accuracy or opinion. However, we wish to thank the Department of Defense for asking bids on the above far-reaching specification—another progressive move.

GT HOT LINE

GE'S AFT-FAN LOGS HOURS . . .

Two General Electric CJ-805-23 AFT-FAN engines have accumulated 250-hours in the company's flight test program at Edwards, California, A Convair 600 toured the East and Midwest recently, demonstrating the engine's exceptionally low noise levels.

"264,000 TURBINE-ENGINE CARS–BY 1965!" . . .

That's the prediction from National Renderers Association–the group whose research will this year produce well over 200-million-lb of high-temperature, fire-resistant synthetic lubricants from animal fats for use by gas turbine industry and others.

RUSSIAN TURBINE BURNS BROWN COAL, PRODUCES POWER 'N HOT WATER HEAT

Russian closed-cycle gas turbine is now in operation, producing both power and hot water central heating. This 12,000-kw unit was built by Escher Wyss and burns brown coal. Incidentally, a smaller but similar German brown coal unit at Ravensburg has now operated over 24,000 hours!

GE'S MACH-PLUS J93 CELEBRATES THIRD BIRTHDAY . . .

General Electric's J93 2000-mph jet is completing its third year of development–right on schedule. Designed and developed in conjuction with USAF, this single-shaft unit is scheduled to power the North American B-70 aircraft . . . also has definite possibilities as power source for other military aircraft, missiles as well as supersonic commercial jetliners of the not too distant future.

WESTINGHOUSE GAS TURBINE IS "BELLOWS" FOR U.S. STEEL . . .

American Steel industry's first gas turbine for blast furnace blowing is now in operation at the United States Steel Corporation's South Works in Chicago. Westinghouse Electric Corporation's turbine supplies air required for blast furnace blowing. (Blast furnace gas is burned as a fuel for the gas turbine.) Installation requires less space than a conventional steam turbine-driven blast furnace blower and boiler–and it uses practically no water. Axial compressor of the turbine supplies 125,000-cu ft of air per minute to the furnaces, in addition to air which is used in the combustion system of the turbine itself.

VARIABLE-CAMBER PROP PROMISES BIG BOOST TO TURBOPROPS . . .

Hamilton Standard's new variable-camber propeller–just awarded a US Navy development contract–promises to make possible some surprising increases in turboprop efficiencies. Takeoff runs can be cut by 15 percent . . . payloads upped by 30 percent . . . range extended 20 percent! Percentages are even better for VTOL aircraft. Secret of H-S's new variable-camber prop is the combining of six or eight blades, mounted in sets of two on a common hub, with rear blades staggered behind the front ones. Combination of low angle for front blade with higher angle of rear blade produces highly cambered airfoil for increased high-lift performance at low speeds. For low-lift at high speeds, blade pairs approach angular alignment. Principle is similar to aircraft wing and use of flaps.

GT INDUSTRY NEWS

McDonnell Aircraft's GAM-72 Quail decoy missile is powered by a General Electric J85 turbojet engine. It's designed to be released in coveys by Strategic Air Command B-52 bombers to penetrate and confuse enemy air defenses.

Sikorsky S-62 is first American helicopter with gas turbine power plant to be certified for commercial operations by FAA. New turbocopter also is world's first amphibious helicopter—built with a flying boat hull permitting operations from land, water, shipboard. GE's T58-6 turbine, similar to one in this helicopter, recently completed 1000-hr of flight time without overhaul and was found to be in excellent condition. A fine turbine for a fine helicopter!

MORE INDUSTRY NEWS FOLLOWS ►

GT CONTRACTS PROCUREMENTS

Some major gas turbine procurements initiated and contracts awarded during recent months by various agencies of the U. S. Government are listed. This material is from the U. S. Department of Commerce publication "Synopsis of U. S. Government Proposed Procurement, Sales and Contract Awards."

• Cincinnati Ordnance District, 230 E. Ninth St., Cincinnati 2, Ohio. "R&D Program, Perform Phase II of the 500 HP Gas Turbine Transmission Integral Power Package, DA-33-008-ORD-1983 (AL-RAD-60-27)"—N/A—$222,440—Allison Div., GMC, Indianapolis 6, Ind.

• San Antonio Air Material Area, USAF, Kelly Air Force Base, Tex. Spare parts, 156 to 1599 each applicable to Compressor Bleed 4303-2840-A12140AT in support of J57 P43 engines and B52 aircraft. (PR SA-0-2915-E12548)"—$120,096—Contract Nr 41(608)-11079 Prod List 5-SA—Holley Carburetor Co., Warren, Mich.

• San Antonio Air Material Area, USAF, Kelly Air Force Base, Tex. "Spare parts, 135 to 14298 each and supporting data. Applicable to J33-A-35, T33 & F-80 aircraft. (PR SA-OC-0-03D-3740)"—$431,783—Contract Nr AF 41(608)-10658, Prod List 43-SA—Bendix Aviation Corp., Bendix Products Div., South Bend 20, Ind.

• U. S. Dept. of Navy, Bureau of Ships, Washington, D. C. "Contract NObs-78468 (Inv. No. 660-032Q) Experimental prototype of a 100-KW, 450-V. 60-cycle variable frequency gas turbine generator set, 1 ea—Switchboard, including gas turbine and electrical control equipment," 1 ea—$97,839—Spec No. SHIPS-G-3492 (as modified)—Curtiss-Wright Corp., Utica Div., Utica, Mich.

• Bureau of Naval Weapons, Washington 25, D. C. "Fabricate and install twenty-four (24) Sound Absorption Exhaust Stacks, for installation on Turbo Jet Engine Exhaust Noise Supressors and twenty-four (24) sets of modification parts for Noise Supressor and Trailer. NOw 60-0132-f"—$141,500—Industrial Acoustics Co., Inc., (International Aerocoustics Division) New York 54, N. Y.

• AMC Aeronautical Systems Center, USAF, Wright-Patternson Air Force Base, Ohio. "Development of the T55-L-5 Engine through Qualification. Used on Army HC-1B Helicopter. (Increase Option) (PR 57169) (MIPR R56-675-TC, Amend. 14); PR 92608 (MIPR R56-675-TC, Partial)"—$1,775,000—Lycoming Div., AVCO, Stratford, Conn.

Purchasing Office, Department of the Navy, Bureau of Naval Weapons, Washington 25, D. C. "Sixteen Gas Turbine Compressors, Contractor's Part No. 376400. NOas 60-0215-f"—$218,327—The Garrett Corporation (AiResearch Manufacturing Co. of Arizona Division) Phoenix, Ariz.

• AMC Aeronautical Systems Center, USAF, Wright-Patternson Air Force Base, Ohio. "T56-A-7 Turbo-prop Engines, 33 each. (For: Installation in the C-130B Aircraft) (PR EP-0-2840-6782)"—$2,937,000—General Motors Corp., Allison Division, Indianapolis 6, Ind.

• U. S. Army Ordinance District, Los Angeles, 55 S. Grand Ave., Pasadena, Calif. "Solar Saturn Model 10MV variable-speed free power turbine"—$73,952—Solar Aircraft Co., San Diego 12, Calif.

• Aviation Supply Office, 700 Robbins Ave., Philadelphia 11, Pa. "Nozzle Assys: To support various aircraft engines. N383-65500A dtd 14 June 60, (383/213253/60)"—various—$61,126—Bendix Products Div., Bendix Aviation Corp., South Bend 20, Ind.

• Aviation Supply Office, 700 Robbins Ave., Philadelphia 11, Pa. "Couplings: Used with air compressor for jet engines. N383-65926A dtd 1 June 60, (IFB 383-725-60)"—various—$48,762—Airaterre, Glendale, California.

• Purchasing Office, Department of the Navy, Bureau of Naval Weapons, Washington 25, D. C. "Thirty-eight Gas Turbine Power Plants less Generator, Model P2 in accordance with Specification MIL-P-8383(ASG). NOas 60-0191-f"—$490,884—The Garrett Corp. (AiResearch Manufacturing Co. of Arizona Division) Phoenix, Ariz.

• Headquarters, San Antonio Air Material Area, USAF, Kelly Air Force Base, Tex. "Overhaul of T53-1-1B aircraft engines AF 41(608)-12001, Call No. 1, 23 June 1960, (PR SA-0-2840-E10049)"—5 ea—$49,039—Lycoming Div., AVCO, Stratford, Conn.

• Headquarters, San Antonio Air Material Area, USAF, Kelly Air Force Base, Tex. "4308-2925-517-8295 (P/N AA15S) Igniter Plug, in support of J57-43W43WA, 43WB, 55 and 59B engines; 4708-2925-293-4810(P/N 33-10S, Igniter Plug, in support of J57-1 thru 39 and 53 engines AF 41(608)-11949, 22 June 1960, (PR SA-0-02925-E-11893)"—5930 ea and 17100 ea——$103,759—Champion Spark Plug Co., Toledo 1, Ohio.

INDUSTRY NEWS . . .

Company-Reported Contracts

• Contracts totaling approximately $10-million are held by **The Garrett Corporation's AiResearch Manufacturing Division,** Phoenix, Arizona. One covers 232 gas turbines ordered by the **Department of the Navy, Bureau of Weapons.** These are to be delivered in several models and configurations.

A second contract has been received from **Convair Division** of **General Dynamics** for 30 trailer-mounted compressors, also housing AiResearch 105 small gas turbines. These units will join previously-shipped AiResearch turbines in providing ground support for the Convair-built Air Force B-58 Hustler.

• A $939,000 order from the **Vertol Division** of **Boeing Airplane Company** for **General Electric** CT58 commercial helicopter gas turbine engines has been announced by the company's Small Aircraft Engine Department. These turboshaft engines will power twin-turbine Vertol 107, Model II helicopter airliners.

• Contract for 100 air turbine starters for the **Convair** 600 aircraft has been received by **Garrett Corporation's AiResearch Manufacturing Division.** AiResearch low pressure model ATS100 starters were chosen by the San Diego division of **General Dynamics** for its latest commercial aircraft. Scheduled for delivery early in 1961, the 600 is a larger, near sonic speed version of Convair's 880 which are also using AiResearch starters.

• **General Electric's** Large Jet Engine Department has announced receipt of a $6,200,000 contract from the **Air Material Command's Aeronautical Systems Center** for further development of the J93 jet engine. Powered by six J93 turbojets, North American Aviation's B-70 Valkyrie bomber will fly at speeds to 2000 mph, or three times the speed of sound.

AMF-Beaird to make and sell The Maxim Silencer

J. B. Beaird Co., a wholly owned subsidiary of AMF, has added the manufacture and distribution of Maxim Silencers and heat recovery units to its lines. Purchase of the Maxim Division from Emhart Manufacturing has made it all possible. Maxim engineers, Donald Bradford, Allen Pease and James Stewart have joined the Beaird staff and are on hand, facilitating the transfer of the specialized machinery used in the production of the silencers.

Ranging in size from the midgets for home lawn mowers to the 58,000 pounders that control jet engine exhausts such as the one in use with a U. S. Navy F8U Fighter, the Maxim line of silencer equipment includes hundreds of designs for industrial engines, ships, high pressure relief valves, etc.

Beaird is well known in the oil, gas and petrochemical industries. The sales agency arrangement remains the same, for the present, with the silencers sold on a world-wide basis through independent manufacturers' agents. Implementing sales of the Maxim products will be the newly created Maxim and LP-Gas Equipment Sales Division under Richard Meisenbach. Aircraft silencer sales continue under Lee Doyle who come over from the Maxim organization.

Turbines Displayed At Hanover Fair

Small gas turbines were predominant at the Hanover Fair of West Germany, particularly the German built transportable units by Deutz and BMW. Larger industrial gas turbines are expected to be on exhibit at the Fair in 1962.

Aerotest Affiliates With Technik

Aerotest Laboratories, Inc. specialists in test engineering (functional, qualification and environmental testing of electronic, mechanical, pneumatic, hydraulic, avionic and fuel system equipment) have announced a working affiliation with Technik, Inc. Affiliation will provide advanced research and development facilities for Aerotest's clients.

Aerotest Laboratories' Lee Permut (standing) confirms new affiliation for advanced research and development, with Dr. Melvin Zaid, of Technik, as Aerotest's H. J. Shapiro observes.

Lee Permut and H. J. Shapiro, principal officers of Aerotest, explained that the personnel of Technik, Inc., includes a team of highly skilled scientists and engineers, proficient in design analysis, applied mechanics and mathematics. They will contribute to Aerotest's activities in the fields of problem formulation, research, analysis, development and design assistance, guidance and interpretation of experimental and production test results.

Clark Turbines Power Trans-Canada Pipeline

Clark Bros. has announced the sale of three Gas Turbine Centrifugal Compressor Sets to Trans-Canada Pipe Lines Limited, as part of the latter's multi-million dollar expansion program to export natural gas to the US. Turbines, to be located in Saskatchewan, are Clark Model 305 Regenerative Cycle, Dual Shaft machines rated at 8370-hp. each (at NEMA conditions).

GT "COMING UP" REMINDER

OCTOBER 2-5 American Institute of Mining, Metallurgical and Petroleum Engineers, Society of Petroleum Engineers, Fall Meeting, Denver, Colo.

OCTOBER 3-5 Institute of the Aeronautical Sciences, Midwestern Meeting on Air Logistics, Tulsa, Oklahoma.

OCTOBER 10-14 Society of Automotive Engineers, National Aeronautic Meeting (including a manufacturing forum and engineering display). The Ambassador Hotel, Los Angeles, California.

OCTOBER 17-18 Institute of the Aeronautical Sciences, CAI/IAS Joint Meeting, Queen Elizabeth Hotel, Montreal, Canada.

OCTOBER 20-22 Acoustical Society of America, San Francisco, Calif.

OCTOBER 25-27 Society of Automotive Engineers, National Transportation Meeting, Hotel Leamington, Minneapolis, Minnesota.

OCTOBER 31-NOVEMBER 2 Society of Automotive Engineers, National Power Plant Meeting, Hotel Cleveland, Cleveland, Ohio.

NOVEMBER 3-4 Society of Automotive Engineers, National Fuels and Lubricants Meeting, The Mayo Hotel, Tulsa, Oklahoma.

NOVEMBER 27-DECEMBER 2 American Society of Mechanical Engineers, Winter Annual Meeting, Statler Hilton Hotel, N. Y., N. Y.

DECEMBER 4-7 American Society of Chemical Engineers, Statler Hotel, Washington, D. C.

DECEMBER 5-8 American Rocket Society, Fifteenth Annual Meeting and Astronautical Exposition, Shoreham Hotel, Washington, D.C.

DECEMBER 17 Institute of the Aeronautical Sciences, Wright Brothers Lecture, Washington, D.C.

4-Engine Jet For Business Use

Firsthand familiarization with requirements necessary for modifing Lockheed's Jet Star to a business executive aircraft was acquired by members of The Garrett Corporation's AiResearch Aviation Service Division during a recent visit to Marietta, Georgia.

SIXTH ANNUAL

GAS TURBINE CONFERENCE and PRODUCTS SHOW

MARCH 5-9 1961

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793 Delafield Ave.,
Staten Island 10, N. Y.
PHONE: Gibraltar 2-3227

"The Defense Department specifically desires that the exhibits to be shown either at the Pentagon or at the Shoreham, be production units for industry."

INDUSTRY NEWS . . .

AiResearch Wins Contract For Eagle APU System

Garrett Corporation's AiResearch Manufacturing Division of Los Angeles has been selected by Bendix Pacific Division, Bendix Aviation, Inc., to join a team of manufacturers developing the Navy's air-to-air Eagle missile. AiResearch, with years of experience in the design of auxiliary power systems, in the last two years has been awarded three out of four major auxiliary power system contracts. They include the Eagle, Nike Zeus and a third classified missile.

Lycoming T 55 Completes 50-Hr Test

Successful completion and acceptance by the USAF of the 50-hr preliminary flight rating test of the T55-L-5 gas turbine engine was announced by Avco Corporation's Lycoming Division.

Test, completed one month ahead of schedule, was run at an average rating of 2190-shp although the present "YT" model specifications call for a guaranteed power of only 1970-shp. The production T55, which will power the Army's new YHC-1B Chinook cargo-transport helicopter will be qualified in August of this year at a rating of 2200-shp.

Halliburton To Use GE Turbine

Laboratory tests of a gas turbine engine being considered as a new power source for Halliburton Oil Well Cementing Co.'s mobile fracturing units got underway last month in Duncan, Okla. Engine is General Electric's 300-lb, 900-hp Model 720 gas turbine. Halliburton has a two-part timetable for the gas turbine engine. For a few months it is being tested under simulated field conditions at the firm's Duncan, Okla., Technical Center. Then it goes into several months of field service on a fracturing truck, serving as the power source for one of the unit's two pumps. Successful completion of the project will mean better overall fracturing treatments, the service company believes.

Garrett Forms German Firm

A new company, **Interaero GmbH,** has been formed by **Hans Liebherr,** a noted German industrialist, and **Garrett International** S.A., Geneva, a wholly-owned subsidiary of **The Garrett Corporation, Los Angeles.** Interaero is designed to meet expanding aircraft business in Western Germany, including the manufacture of Garrett designed air conditioning and pressurization system, electronic central air data systems for the Lockheed F-104G (German) airplane and similar equipment for the Fiat G.91 (Italian) airplane. Interaero will sell, manufacture, repair and overhaul certain products now produced by Garrett's AiResearch Manufacturing Divisions in Los Angeles and Phoenix. In addition, it will conduct various research and development programs utilizing Garrett technology.

Plans call for immediate construction of a manufacturing plant to be built in southern Germany. Included on Interaero's board of directors are **Hans Liebherr, Bryan S. Clark,** Garrett's director of foreign operations; **Dr. W. T. von der Nuell,** Garrett's director of turbomachinery planning; and **Dr. Hans Donner,** a German business consultant.

Off-Shore Rigs Use New Sikorsky S-62

Petroleum Helicopters, Inc. is now using gas turbine-propelled Sikorsky S-62 omniphibious helicopters for serving offshore oil rigs in the Gulf of Mexico. The oil rigs have switched from piston-engined boats to high speed 'copters and now have a much faster service available, of course powered by gas turbines.

For more information write in No. 107

100-Knot Speeds Seen For Hydrofoils

An RCA scientist is predicting ocean travel at speeds exceeding 100-knots within 10-years! Dr. R. C. Seamans, Chief Engineer of the RCA Missile Electronics and Controls Division, claims recent developments in automatic control systems for boats now make possible commercial and military use of "hydrofoils". "These vehicles can be built in sizes between 500 and 1000-tons, with the ability to maintain speeds between 50 and 100-knots under adverse weather conditions," said Dr. Seamans.

He added that to maintain a steady platform and high speed in heavy seas, the fully submerged (super-cavitating) foil system with automatic controls is needed. He said the RCA control systems enable hydrofoil craft to maintain a constant craft height above a mean water level. At times when wave height is less than hull clearance, or, when the wave height is greater, RCA's system enables craft to follow the waves on a partial contour.

Pratt & Whitney's J-52 Powers Navy Aircraft

New jet engine for missiles, the J-52, has been installed for the first time in a plane. Grumman's A2F-1 Intruder, (Navy's latest attack bomber), was picked to receive two P&W J-52's, each delivering a 8500-lb thrust. It's a lightweight plane (24,000-lb empty) and requires a lightweight jet engine. There's a new twist to the tailpipes—they're tilted down approximately 27° so that they can push the plane upward and also allow the plane to fly as slow as 90-mph.

Mitsubishi To Build Sikorsky 'Copters

License to manufacture and sell twin-turbine S-61 helicopters has been granted Mitsubishi Heavy Industries, Ltd. of Japan by Sikorsky Aircraft. The S-61 will be built at the Nagoya Aircraft Works of Mitsubishi, where the Sikorsky S-55 helicopter has been produced under license since January 1958.

Lycoming And Deutz Sign Sales-Manufacture Agreement

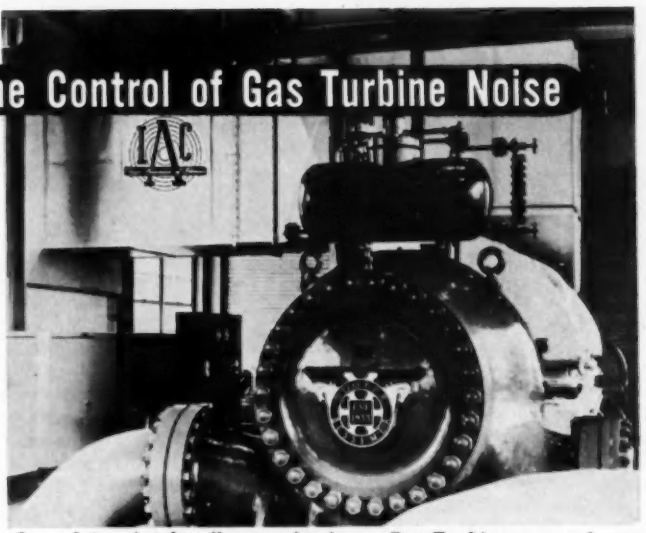
An agreement covering the sale and manufacture of Lycoming T53 and T55 gas turbine engines in Europe has been signed by Avco Corporation's Lycoming Division and Klockner-Humboldt-Deutz, Cologne, West Germany.

The T53 is currently in volume production at Lycoming's Stratford, Connecticut plant—in both helicopter and turboprop versions while the more powerful T55 helicopter model is scheduled for production later this year.

Deutz is the oldest manufacturer of internal combustion engines in the world, dating back to 1864. Lycoming, which began producing engines more than 50 years ago, has been active in the turbine field since 1951 when they were awarded a military contract for development of small a helicopter turbine.

(Continued on page 39)

For the Control of Gas Turbine Noise



One of two intake silencers for large Gas Turbine powered compressor in a gas pipe line transmission facility.

Intake silencer for gas turbine powered locomotive being fabricated at Industrial Acoustics Company plant.

IAC "Universal" UDAC Ground Run-Up Exhaust Noise Suppressor being moved into position for silencing a DC-8 Jet Transport.

Industrial Acoustics Co., Inc. is the foremost designer and manufacturer of Gas Turbine Silencers for Industry and Aviation.
Intake and Exhaust Silencers designed for hundreds of installations during the last several years range in capacity from 2 lbs. to 300 lbs. per sec. mass engine flow.

Our Engineering Department will gladly work with you in solving your noise problems.

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For more information write in No. 96

GT PEOPLE PLANTS PLACES

Principals in groundbreaking ceremonies for Columbia Gulf Transmission Company's experimental jet gas turbine station were (left to right): J. David Francis, Chairman, Kentucky Public Service Commission; Gene Miller, President, Cooper-Bessemer Corp.; John Partridge, President, United Fuel Gas Co.; E. Bruce Kennedy, Commissioner, Kentucky Department of Economic Development; Ralph Boyer, Vice President, Cooper-Bessemer; P. W. Pratt, Vice President, United Aircraft Corp.; S. Orlofsky, Vice President, Columbia Gulf Transmission Co., and John W. Kelley, President of Columbia Gulf.

Executive Changes Announced In Allison Aircraft Engine Operations

Seven **Allison** personnel changes in the **Aircraft Engine Operations** have been announced by **E. M. Deckman,** manager of sales and contracts.

Reporting to **N. E. Eggers,** manager of engine and propeller sales, are **R. H. Ludington,** supervisor of jet engine sales; **R. E. Lowry,** supervisor of small engine sales, and **D. R. Orme,** supervisor of Aeroproducts sales.

J. D. Beaumont, supervisor of prop-jet conversion engines, will report to **J. T. Wills,** previously anas head of prop-jet engine sales.

Assigned to product planning analysis and rocket sales under Manager **R. L. Coffey** are **C. H. Clark, Jr.,** rockets and nozzles; **F. C. Spinney,** research, and **C. B. Gaugh, Jr.,** product planning.

Promotions At Solar

Robin Schmidt has been promoted to director of public relations and advertising for **Solar Aircraft Company,** according to President **Herbert Kunzel,** Schmidt joined Solar in the public relations and advertising division in 1957. Prior to that he was a public relations man with Pacific Finance Corporation in Los Angeles, and a newspaper reporter with The Los Angeles Times and other newspapers.

Morris Sievert has been named manager of turbo-machinery sales for Solar Aircraft Company, it was announced by **L. D. Richardson,** vice president-sales. Sievert has been in turbomachinery sales with Solar since 1957. Prior to that he was district territory sales manager for the Elliott Company, Jeanette, Pa., Manufacturer of turbomachinery equipment.

Pall Corporation Names Henry Petronis

Dr. David B. Pall, President of **Pall Corporation,** Glen Cove, New York, announced the election of **Mr. Henry Petronis** as Vice-President-Manufacturing, in addition to his present function as president of **Glen Components Corp.,** precision machining subsidiary of Pall Corporation. Pall Corporation manufactures porous metals and filters for aircraft, missile, atomic energy and process industry applications.

Carlson Moves Up In GE's Gas Turbine Dept.

Harold A. Carlson has moved up from Sales Manager to Manager-Electric Utility and Transportation Sales for **General Electric's Gas Turbine Department.** This was announced by **Whitman Ridgway,** Manager-Marketing for the department.

Following graduation, Carlson joined General Electric in 1950 on its Test Program. From 1951 to 1953 he was a design engineer with the company's Aircraft Gas Turbine Department at Evendale, O. In late 1953, Carlson was transferred to the Large Steam Turbine-Generator Department marketing section in Schenectady. In 1955, he became a proposal engineer in the Gas Turbine Department and later the same year was named Sales Manager-Electric Utility and Transportation Sales, the position he has held until his current assignment.

New European Research And Development Office

In response to a long felt need on the part of a number of American manufacturers with international interests, **Northern Research and Engineering Corporation** has begun the formal operation of a research and development office in London, England. The office which opened July 15, 1960, will be under the direction of **Dr. David Wilson,** Resident Technical Director. The company's work includes gas turbines and its many related fields.

R. E. Palmer

Richard E. Palmer Moves Up To Manager

The appointment of **Richard E. Palmer** as manager of **The Garrett Corporation's AiResearch Manufacturing Division** of Los Angeles, was announced by **Harry W. Wetzel,** manufacturing group vice president. Palmer, associated with AiResearch for more than 18 years, will direct the activities of more than 4500 engineering, administrative and production specialists in the Garrett division, one of the largest aircraft and missile component manufacturers in the United States.

GE's Weymouth Moves Up

Richard E. Weymouth has recently been named manager of applications engineering at **General Electric's Commercial Engine Operation** near Cincinnati. In this new position, Weymouth will be responsible for investigating future applications for GE's large commercial engines. These include growth versions of present jet airlines, commercial cargo aircraft, and the supersonic transport.

Clark Bros. Sales Appointments In South Texas Area

Stewart L. Babbitt, formerly service manager, Houston, was named sales engineer for that office of **Clark Bros.** He will be assisting with the sale of Clark engines, compressors and gas turbines.

G. M. Woodman, moves to the Houston district as small engines salesman. He served in that capacity in Corpus Christi.

C. R. Apitz has been assigned to the Houston office as senior sales engineer. He was special representative, gas turbines, in Dallas.

F. J. Shaw, application engineer, Houston, goes into the Corpus Christi area as sales engineer, handling the entire Clark line.

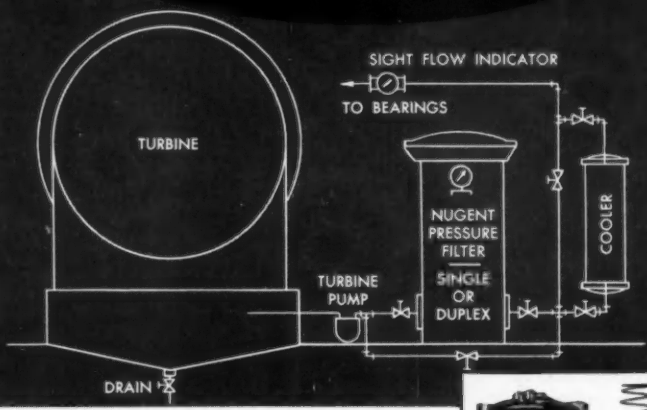
Pratt & Whitney Diversifies

Establishment of a new Industrial Power department to develop new applications of existing products and design new products for use in the industrial power field was announced by **Pratt & Whitney Aircraft division of United Aircraft Corporation.**

L. C. Mallet, general manager of P&WA, said the formation of the new department will expand the division's product lines by diversification within the broad area of power generation. New department will be headed by **William J. Closs,** presently chief of the company's experimental test laboratories.

In the past year, Pratt & Whitney Aircraft has been increasingly active in research and development of new power sources, including the adaptation of aircraft gas turbine engines to ground power uses.

LUBRICATING OIL FILTERING SYSTEMS for GAS TURBINES



NUGENT builds them to your requirements

Nugent is staffed and equipped to furnish lubricating oil filtering systems for any gas turbine . . . to your most exacting specifications.

Nugent systems filter all the lube oil in circulation every cycle, removing foreign solids 5 microns and smaller. Additives are not disturbed, yet oil is kept clean. Harmful impurities cannot reach vital parts to accelerate wear.

Whether you need a single filter or a complete system, Nugent quality products are your best buy. Contact us today for complete information.

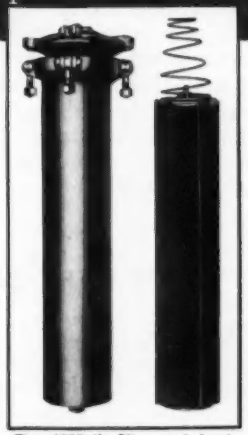


Fig. 1555-4L filter and laminated disc cartridge provide excellent micronic efficiency.

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ACCESSORIES

An Important Key to Performance

Here is a rundown on some accessory items commonly used on or with gas turbines and produced by some of the better-known suppliers to the industry.

START WE MUST . . .

THERE ARE MANY WAYS to start gas turbines —with air, prime movers or electrical power. However, with the advent of the smaller gas turbine engines (100 to 1000 hp), lightweight d-c starter-generators are finding more and more use in both aircraft and ground applications. Small and compact, the units provide efficient engine starts and, in addition, *reliable d-c- electrical power.*

One leading manufacturer in the electrical power generation field—Red Bank Division of The Bendix Corporation—has come up with a complete new family of d-c starter-generators. Units range in rating from 30 to 500-amp 30-volt d-c power and the largest unit will provide up to 98-lb ft torque at about 1100 rpm when supplied with a constant current of about 500-amp 30-volt d-c.

For starting a jet engine, the starter-generator is fed a constant current supply—usually about 400 amp for generators rated above 200 amp, and about 2 to 2½-times the rating for generators rated under 200 amp. At this point, the generator operates as a motor and begins to turn over the turbine. When the turbine reaches "light-off speed", it takes over and begins driving the generator which then produces d-c- electrical power.

Red Bank has also developed a family of brushless a-c generating systems and they are currently testing jet engine starting capabilities of these units. By exciting this generator, it will run as a synchronous motor to turn over the turbine, just as the d-c generator does. This new approach to jet-engine starting will certainly be watched with interest.

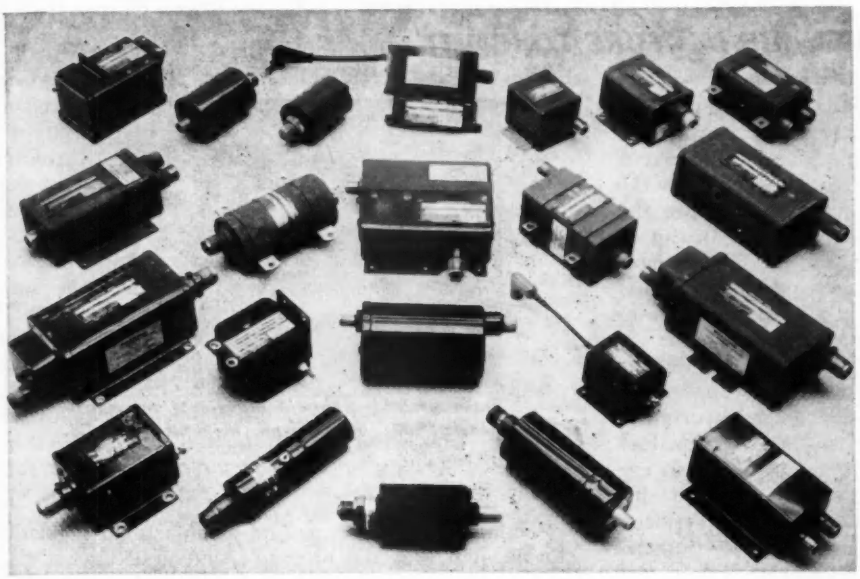
Red Bank's DC starter-generator 15-lb, 5-in. 30B56-1/100 amp unit, designed specifically for gas turbines rated around 250-hp.

AT "LIGHT-OFF" SPEED, COMES IGNITION . . .

IT'S TAKEN MANY YEARS to arrive at the ignition system now used on many gas turbine installations. Basically, the old inductive type has given way to the capacitor type. The inductive type in the piston engine must operate continuously and inherently creates a spark giving spark plugs a long life. Fortunately, the gas turbine does not require a continuous spark and can therefore use a much more powerful direct-acting charge and still have a long spark plug life. The capacitor system also gives a wallop that will break down any dirt or other impurities at the spark plug.

During this transition period many ignition systems and many kinds of spark plugs were tried on gas turbines. The Holthouse ignition was an improvement over conventional inductive types as it had the dual feature now found on the capacitor type—an ionizing discharge followed by the main long-lasting spark. This Holthouse system was used not only on gasoline engines but on natural gas engines and gas turbines with success.

On large gas turbines we find, at times, a spark ignition that lights a gas flame and this flame burns continuously in the combustor until the turbine comes up to load. In the large industrial gas turbine with its single or multi-fueled combustor head there is more of a problem. If the turbine burns a heavy oil under load, it may burn a light oil to start. This is preferred



22 ignition units built by Scintilla Division of Bendix specifically for many types of gas turbines. A remarkable array!

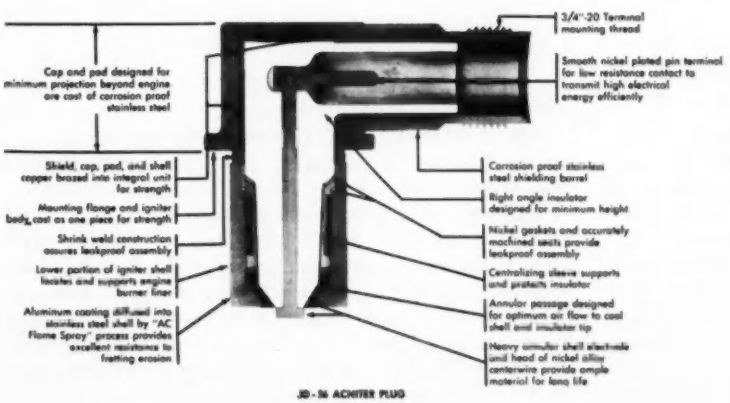
from the ignition viewpoint and the gas flame does help when the combustor is of 3, 4 or even 6-ft diameter. However, spark ignition is generally required even if ignition in the combustor goes from spark to gas to light oil and finally heavy oil.

Getting back to straight spark ignition and specifically the capacitor type, let's quote from a manual about Bendix-Scintilla ignition: "Our gas turbine ignition systems, generally, fall into two main categories—High-Tension and Low-Tension Systems. The High-Tension capacitor-type unit such as the TCN-18 stores a large amount of energy at relatively low voltage in tank capacitors. The spark discharge consists of two parts: the ionizing spark—a high-frequency, high-voltage, low-energy discharge—and the ignition spark which is a low-voltage, high-energy type discharge. The low-tension TGLN units are similar to the high-tension capacitor discharge systems. They differ only in that the ionization spark is accomplished by a self-ionizing material in the igniter plug.

"Scintilla has designed and manufactured every variation of jet and gas turbine ignition for which there has been a need. We have single and dual-ignition units powered by a-c or d-c current or the self-contained magneto unit, providing inductive or capacitor discharge sparks, embodying either the high or low-tension principles of ignition. We manufacture units with stored energy ranging from 0.01 to 20.0 joules, with or without radio filters. There are units designed for continuous duty or intermittent duty only. Our products include systems which will operate over various temperature ranges from −65° to +500°F, and above."

There are other fine capacitor ignition systems. However, the Bendix Capacitor System was chosen for discussion here because of opportunity to observe their developments through the years from their pioneering efforts in producing an ignition system for gas turbines. This was done and in the early years, gas turbine men found an ignition system they could call their own—the capacitor system.

CAPACITIVE DISCHARGE GOES TO AN IGNITER . . .


3/4"-20 Terminal mounting thread
Smooth nickel plated pin terminal for low resistance contact to transmit high electrical energy efficiently
Cap and pad designed for minimum projection beyond engine are cast of corrosion proof stainless steel
Shield, cap, pad, and shell copper brazed into integral unit for strength
Mounting flange and igniter body cast as one piece for strength
Shrink weld construction assures leakproof assembly
Lower portion of igniter shell locates and supports engine burner liner
Aluminum coating diffused into stainless steel shell by "AC Flame Spray" process provides excellent resistance to fretting erosion
Corrosion proof stainless steel shielding barrel
Right angle insulator designed for minimum height
Nickel gaskets and accurately machined seats provide leakproof assembly
Centralizing sleeve supports and protects insulator
Annular passage designed for optimum air flow to cool shell and insulator tip
Heavy annular shell electrode and head of nickel alloy centerwire provide ample material for long life

JD-56 ACNITER PLUG

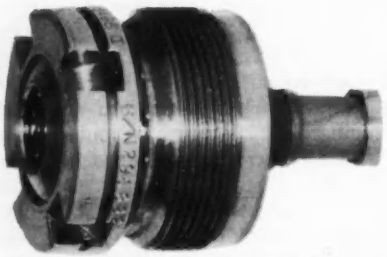
JUST as there is a difference between induction coils and capacitors, spark plugs or igniters also differ. Here's a good example of an igniter, a popular model for gas turbine use that is built by AC Spark Plug Division of General Motors. It shows the typical rugged construction and the heavy electrodes needed with the high-energy capacitive discharge.

THERE MUST BE A FUEL/AIR MIXTURE TO IGNITE . . .

GETTING ATOMIZED FUEL into the combustion air is the job of the fuel nozzle. One company that has specialized on gas turbine fuel nozzles is Delavan Manufacturing Company. They have shared with the gas turbine industry the tremendous expansion of the past 14 years. And Mr. N. B. Delavan, Chairman of the Board of Directors, puts it this way, "If we have a secret for the tremendous growth our company has enjoyed in this period, it lies clearly in the imagination and skill of our people, still our greatest resource."

To show the importance Delavan has placed on this portion of its business, the company recently announced organization changes in its engineering department which specifically places development of gas turbine fuel injectors and accessories apart from other Delavan engineering activities. This new, separate division, announced by H. F. Rothwell, Delavan vice-president for engineering, will be managed by Paul D. Burgess.

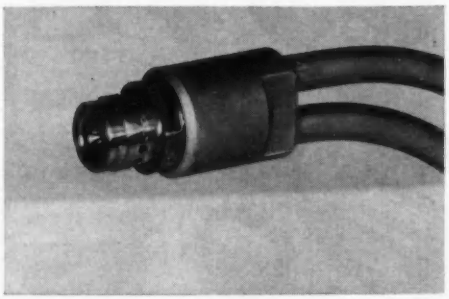
Delavan is to be congratulated for their faith in the industry and for their excellent know-how that has produced specialized equipment including nozzles and



Typical nozzle built by Delavan Manufacturing Company . . . mass produced for jet units.

advanced-type fuel injection devices. They have gained extensive experience in the design and manufacture of main engine, igniter and after-burner fuel nozzle injectors including the following types:

Simplex	Bypass, Return Flow
Dual Orifice	or Spill Types
Dual Orifice with Flowdivider	Air/Liquid
Variable Area	Impinging Jets



Experimental gas turbine heavy-duty automotive nozzle built by Delavan Manufacturing Co.

Certain of these nozzles are manufactured regularly for flow ranges as high as 50 to 1, and on occasion Delavan has furnished nozzles providing good atomization over flow ranges as high as 100 to 1. Nozzles with guaranteed flow tolerances not exceeding ±1% at maximum flow rating and other close tolerances at ratings less than maximum are furnished as production items. These nozzles must operate reliably under extremely high and low environmental temperatures and on regular and special hydrocarbon fuels.

In line with design and manufacture of precision nozzles, test equipment has been developed which will permit extraordinary accuracy in flow testing and the close control of test variables.

All of this specialized experience on fuel nozzles and injectors has earned production programs for Delavan with companies such as Pratt & Whitney Aircraft, General Electric, Ford Aircraft Engine Division, Westinghouse, Lycoming and others. In fact, in August of 1959 Delavan completed the one-millionth fuel nozzle for Pratt & Whitney Aircraft's J-57 engine.

Delavan nozzles are used in the following applications: Gas turbine locomotives; gas turbine stationary power plants; marine turbines; missiles; aircraft jet units; helicopter gas turbines; APU air-ground installations; heavy construction equipment; turbines for pumping and for automotive applications.

AND FUEL MUST BE CONTROLLED . . .

All prime movers require some device for fuel control. Type and performance characteristics of the control will vary considerably, largely dependent on what the prime mover is required to do in its normal work cycle. Speed and load are dependent variables and most fuel controls include speed-sensing mechanisms. Three such fuel controls, including one designed for overspeed control, are discussed.

WOODWARD GOVERNOR COMPANY, long in the business of governing having started with steam engine and hydraulic turbines, is now well entrenched in the governing of gas turbines of all types.

Let us look at one application. Woodward, with several thousand governors on diesel locomotives, also builds the governors used on the latest gas turbine locomotives now operating on the Union Pacific. These locomotives are rated 8500 horsepower. The turbine is a single unit with a single shaft driving a gear box which in turn drives four traction generators.

Turbine speed is controlled by a Woodward PG hydraulic governor specially modified to suit the functional characteristics of the gas turbine. The governor has its own oil supply and is driven by the turbine through reduction gearing. It is essentially isochronous and will maintain constant turbine speed regardless of load.

To protect the turbine from overheating, a temperature piston assembly limits governor power-piston travel when exhaust temperature reaches or passes an established maximum. In the event that a load change exceeds the control limits of the temperature piston assembly or the normal fuel rate system, a rack and pinioned-geared load-control piston will move the load-control rheostat toward the minimum field position to reduce generator excitation and relieve load.

A jump and rate system is incorporated in the governor to handle large, sudden increases in load. This allows very rapid movement of the power piston in the "increase" fuel direction within limits preset by a jump piston. When the jump piston hits its stop, power piston movement then proceeds at a rate controlled by the fuel rate chopper valve.

In addition to building heavy-duty governors for locomotive use we find Woodward building fuel controls for practically every type and size of gas turbine engines, including power for boat propulsion, aircraft propulsion, ground power units, standby generator sets, pumping units and airborne powered-generator sets. Many of these applications involve extremely high and low temperatures. Tests required on some units call for as high as 800°F. and units must also operate satisfactorily at −65°F.

The Woodward type 1307 fuel control shown in the photograph is another example of Woodward's high-precision equipment. This is one of a family of accurate, reliable, lightweight fuel controls produced for use on high-performance, turbo-jet engines within the 10,000 to 20,000-lbt range. Functions of the 1307 include maintaining engine rpm according to throttle schedule . . . scheduling acceleration and deceleration fuel rates . . . controlling position of inlet guide vanes . . . providing exhaust nozzle area control with an interlock signal when engine is accelerated at maximum fuel rate . . . and furnishing afterburner control with a pressure signal as a function of power lever position and engine speed.

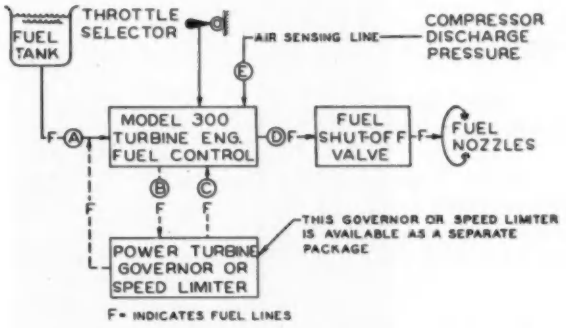
Woodward's main fuel control for GE's C-J805 jet engine used on Convair 880 and 600.

OF THE MANY ACCESSORIES built for 200 to 500-hp gas turbines by AC Spark Plug, the Electronics Division of General Motors, the Model 300 Fuel Control is one of the most popular. All in one compact 6-lb unit, it contains a positive-displacement pump; turbine speed-selecting droop-type governor; a starting, acceleration and minimum fuel flow control with regulator and filter. It can handle JP, gasoline, kerosene and diesel fuel through an ambient temperature range of −40°F to 160°F.

The fuel pump is capable of a 4.5-psi lift of fuel thereby eliminating necessity for boost supply pressure in most applications. The pump is sized to produce a greater flow than required by the engine, by-passing excess flow to the pump inlet when maintaining the required governor fuel flow or the schedule desired for starts and accelerations.

The control utilizes the very reliable flyweight principle for governor operation. Excellent insensitivity to dirt throughout the control permits use of only a screen-type fuel strainer.

Starting and acceleration fuel flow schedules are determined by a compressor pressure sensor. The governor break slopes are characteristic of the flyweight speed head system and can be altered to meet customer requirements. Minimum fuel flow can be varied within a finite range which is determined by design. A percentage type of field adjustment is incorporated for adaption to specific engine demands.



Fuel control diagram—AC Spark Plug Electronics Division, GM.

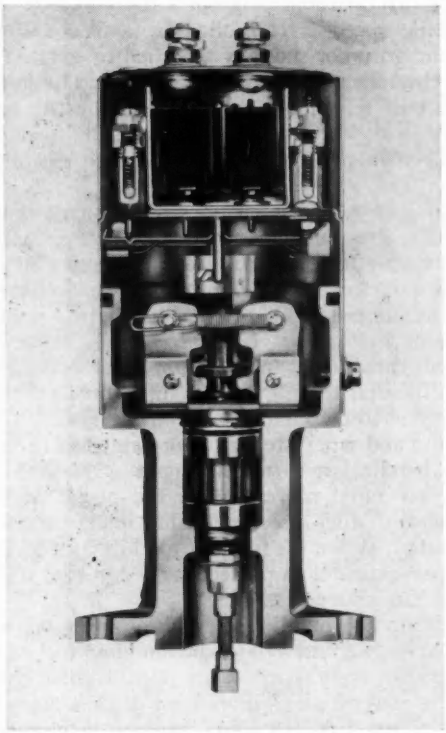
SYNCHRO-START PRODUCTS, INC. of Skokie, Illinois entered the gas turbine field in 1951, installing an over-speed switch on a Boeing 502 turbine. This first switch was a forerunner of their complete line for gas turbines.

The 2-element unit shown contain two separate contacts which operate at two different speeds. When applied to either gas turbines or any other type of engine, the low-speed contact is usually used to disconnect the starting circuit after the unit begins to run under its own power. The high-speed contact is used to provide overspeed protection in case of speed control governor failure.

Three-element speed-sensitive switches are generally used in the more sophisticated control systems. The low-speed contact is used to energize the ignitor circuit after the starting motor has gotten the turbine up to recommend speed. The intermediate-speed contact is used to disconnect the ignitor and starting motor circuit after the turbine begins to run under its own power. The third and high-speed element is then used for over-speed protection in case of speed control governor failure.

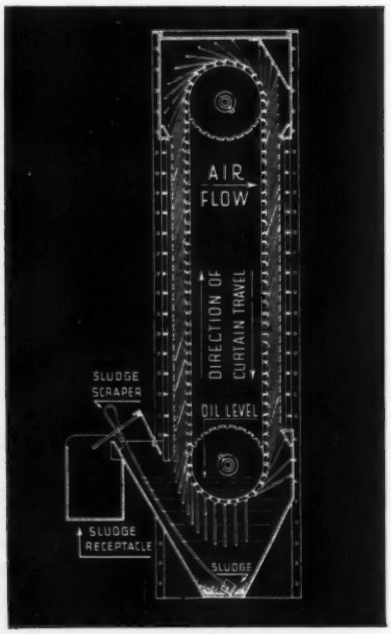
All speed switches are available with a number of different drive arrangements. Generally speaking, for turbine applications, the GA style, illustrated, which mounts directly on an AND 20005 engine tachometer pad, is the most popular.

Synchro-Start produces other gas turbine control equipment including overspeed and underspeed governors and various dual drives, speed increasers and other accessories and specialty controls.



GA-2 two element Speed Sensitive Switch. Spring and switch (top left) is low-speed switch, high speed switch on right. Flyball weights shown (center) with one of two weight-retarding springs.

ALL THAT AIR USED MUST BE CLEAN . . .



Illustrates AAF Multi-Duty filter's self-cleaning, screen-coating action.

When one takes a look at the impressive list of gas tubine air filter installations made by American Air Filter Company since 1947 one realizes the real importance placed on good air filtration. Over 200 separate installations have been made by AAF ranging in size from 10,500 cfm to 458,000 cfm. Practically all are large, averaging from 70,000 cfm to 140,000 cfm.

These filters are used in practically every application including: Stationary and portable power plants; main and feeder pipe lines; compressor plants; chemical plants; refineries; butadiene plants; cement plants; and blast furnace applications.

Many types of filters are used in these installations including "Evaporative Washer", "Multi-Duty", "Roll-O-Matic", "Renu-Vent glass filter", and filters especially made up to meet local requirements.

These air filters were either purchased by the gas turbine builders or direct by the operating companies. The list of operating companies is so extensive it cannot be published here. However, gas turbine builders listed include:

Brown Boveri Co. of Baden, Switzerland
Clark Bros., Olean, N. Y.
General Electric, Schenectady, N. Y.
Oerlikon, Zurich, Switzerland.
Richardsons Westgarth Ltd. of England

Ruston & Hornsby Ltd. of England
Solar Aircraft Co., San Diego, Calif.
Westinghouse Electric Corp., Philadelphia, Pa.

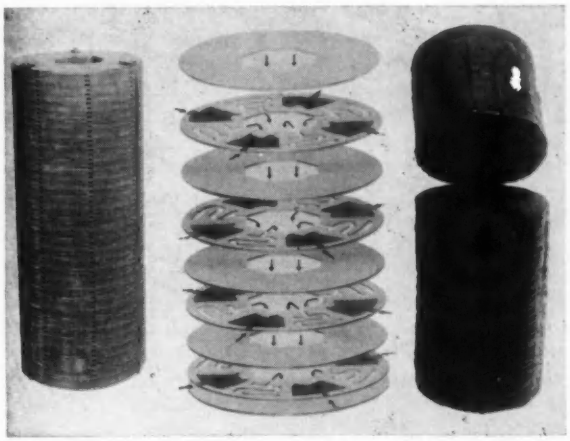
Typical installations are those along the 1068-mile Trans-Arabian Pipeline System. Dust storms and 120°F temperatures are frequent along this pipe line from oil fields near the Persian Gulf to the offshore loading terminal on Lebanon's Mediterranian coast.

Unattended portable and permanent gas turbine pumping units along this line, with power equipment capable of moving 460,000 bbl per day, are protected by AAF's high-effiicency, self-cleaning filters.

FUELS AND LUBES MUST BE CLEANED TOO . . .

Primary function of both fuel and lube oil filters is removal of contaminants that will impair the system's operating efficiency. Fuel filters remove such foreign matter as atmospheric dust, dirt introduced during handling or storage, moisture, scale and rust. For lube oils, core sand, metal chips, wear metal, carbon soot, and limited amounts of combustion byproduct contamination must be added to the list.

Looking at this list it is apparent that most of these contaminants are hard and abrasive and will result in excess wear rates. Others, alone or in combination, can result in sludging or formation of corrosive acidic materials. One serious result of sludging is that it may build up on passage walls, restricting flow. Today's filters, properly installed and regularly serviced, will remove all contaminants in sizes down to 5 microns and smaller and insure clean systems for best gas turbine performance.



Hilco disc-stack element new at left, exploded to show oil flow paths. Used element, right, split to show dirt load.

HILCO FULL-FLOW FILTERS, produced at Elmira, N. Y. by the Hilliard Corporation, are well known throughout the world. Their "F" Series Hyflow filters accommodate various numbers of replaceable filter elements, the size, and hence the number of filter elements, being selected to suit the gpm flow requirement and the permissible pressure drop.

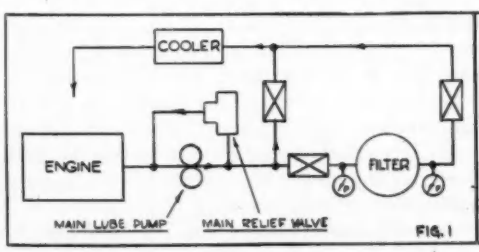
Filter casings are of all-welded steel construction with the cover retained by swing bolts and having a quick-action cover lifter. "In" and "out" pressure gauges are included to measure pressure drop across the filter elements. Internal or external bypass valves can be provided to insure oil flow if for any reason the filter elements become plugged.

Two types of filter elements are available. Their Type PW-718 is a special paper disc-stack element. Alternate discs are cut out from the periphery toward the center outlet hole in a regular pattern. This provides considerable extended surface to reduce flow restriction while at the same time increasing dirt-holding capacity. Micro filtration in depth is obtained.

Type PL-718 was developed recently to meet U.S. Military full-flow filter element specification MIL-F-20707 and has received type approval. This element is fabricated resin-impregnated pleated paper and is completely metal clad. Pleated design provides great extended area and the cartridge has extremely high flow rates combined with micronic filtration.

Full-flow filters can be installed in single or dual parallel arrangement. When one is installed, provision is made for a bypass line (see illustration) to isolate the filter for servicing while still providing lube oil to the turbine. A similar arrangement can be used in the fuel supply system.

A dual filter system (also illustrated) has the advantage of continuous filtration even during periods when one filter is being serviced. This offers maximum protection in installations where operation is substantially continuous. The principle of this system applies equally in fuel supply systems.



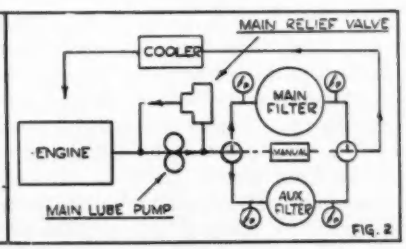


Fig. 1 shows typical full-flow filter installation. Fig. 2 shows full-flow installation using dual filters where bypassing of unfiltered oil is not permitted.

WM. W. NUGENT & COMPANY has been providing filters for gas turbines since 1939. Their first installation is shown. They have been prime mover filtration specialists for over half-a-century and have developed a wide range of filters and filtering media.

Mr. W. Nugent's first lube oil filter installation in a gas turbine plant. This was in 1939 on a Brown Boveri unit of Sun Oil Company at Marcus Hook, Pa.

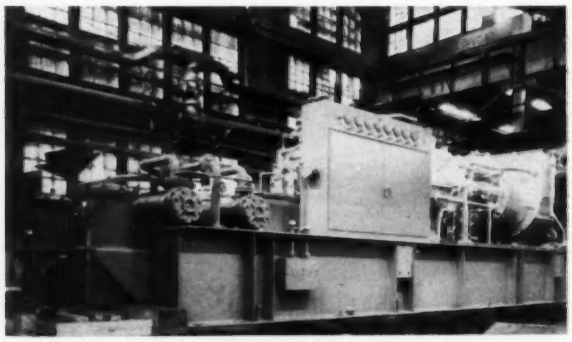
Their filters are built for heavy duty and in various sizes to accommodate the required number of filter elements to provide the necessary flow rate, pressure drop and element service life. For quick servicing, covers are retained with swing bolts and in the larger sizes have lifting gear. A differential pressure gauge measures pressure drop across the elements. A bypass pressure relief is built in. Filters can be used individually or a duplex unit provided.

While various filtering media are available and, in fact, can be used interchangably in the filter, Nugent specializes in a high-quality laminated disc-type element. This provides a high flow rate at low pressure drop with the micronic filtering absorbtion and neutralizing properties of a depth-type filter. The element is a stack of similar discs of crenelated shape. Each is turned 45 deg from its adjacent discs such that the crenelations overlap the open areas. The voids created vastly extend the effective surface area.

Liquids entering the voids must flow through the controlled-density disc material to the center outlet. Solid particles as small as 3 to 5-micron size are removed and the element will absorb approximately twice its original weight of these particles before replacement is necessary. No chemicals or bleaches are used in the disc construction. They will not directly remove additives from detergent oils. Acid forming and sludge forming contaminants are removed.

Used in the fuel oil system, these elements provide positive protection against clogged injection systems or faulty combustion due to foreign matter in the oil. Location can be on the pressure or suction side of the supply pump. On the suction side it has the advantage of protecting the pump as well but in this case the pump must be capable of sufficient vacuum to provide free flow in sufficient volume to the turbine's fuel system.

Nugent was one of the first to advocate full-flow filtration where all the lube oil reaching bearings and critical parts is cleaned every cycle. They point out that the gas turbine uses little oil when it is properly filtered. As to filter life, the contaminant load is far less for the gas turbine than for many other prime mover types. In the Brown-Boveri installation shown, the filter operated one year before cleaning and the lube oil was not changed. In several G-E installations the same service has been obtained and no oil change was required.



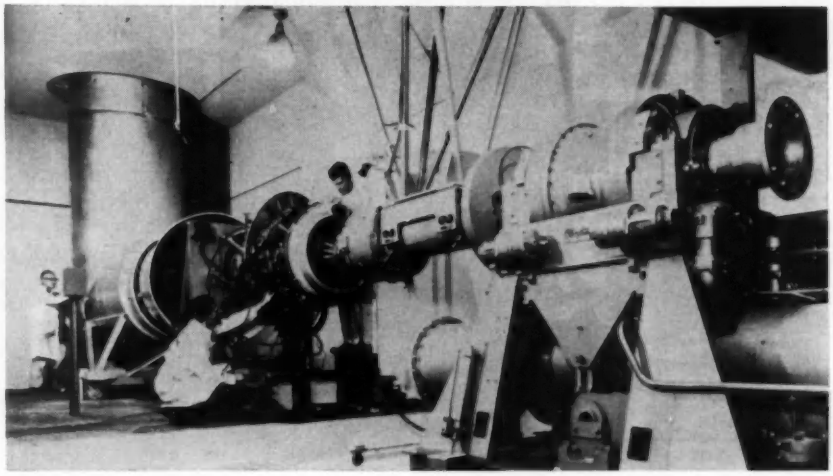
Arrow on left shows Nugent duplex lube oil filter 1555-414 mounted on GE's 7000-hp gas turbine. Unit is in East Texas.

THEN THERE'S TESTING EQUIPMENT . . .

SPACE simply doesn't permit more than token coverage of the many items of test equipment used. Since a major criterion of performance is power and, industrially, the main use of gas turbines is to provide shaft power, a dynamometer for turboprop engines was selected for discussion.

"Conversion of an engine test cell from pistons to turboprops has been accomplished for Eastern Air Lines at Miami by the George L. Nankervis Co., Detroit". This is only one such statement read recently. In the text of "Airlift" for July is "Use of a Clayton Manufacturing Company (El Monte, Calif.) dynamometer instead of a conventional propeller for power absorption improves accuracy of test data and cuts installation time for an engine under test from an hour-and-a-half to 15 minutes. A significant side effect is a reduction of noise during testing."

The above is only one of the many test facilities al-



Rolls-Royce Dart engine installed and connected to Clayton Dynamometer at Pacific Airmotive test cell. It's capable of handling all known turbo-prop sizes.

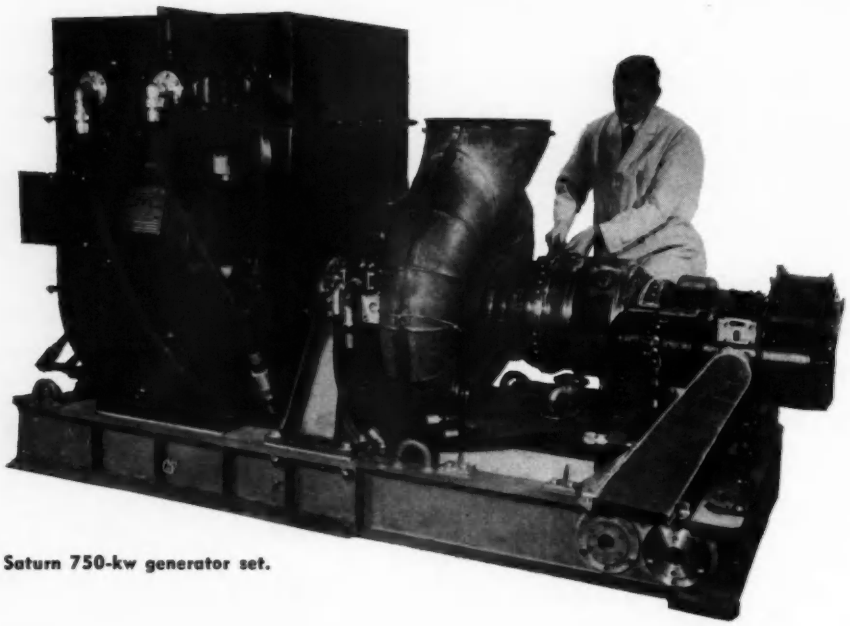
ready changed or changing over to test turboprops by dynamometer. G. R. Marshall, manager, Special Products Division of Clayton furnish a list of their installations. Some well-known names are included.

AirWork Corporation	Standard Aero Engine Ltd. (Canada)
Allison Division, GM	Pacific Airmotive Corp.
Dallas Airmotive, Inc.	Rolls-Royce of Canada, Ltd.
Eastern Air Lines, Inc.	Naval Air Material Center
Northwest Airlines, Inc.	U.S. Air Force

Many of these facilities are set up to test all known European and American turboprop engines, some have initial limited capability for testing specific engines. It is a good thing to keep in mind that test facilities for shaft-type gas turbines are located throughout this country and in Canada. Also, that excellent dynamometers covering a broad horsepower range have been developed and are available with application to both aircraft and industrial shaft turbines.

ARMY'S JEEP CHANGES "HORSES"

WILLIAMS Research Corporation's president Sam Williams demonstrates to Detroit Ordnance Arsenal's Sgt. Roger L. Bernier how his lightweight 75-hp gas turbine will look when it's located under jeep's hood. Scheduled to be tested in an Army jeep soon, contract for test has been awarded Williams Research by Detroit Ordinance District, under technical supervision of Ordnance Tank Automotive Command in Detroit. Williams indicated that the weight advantage of gas turbine-powered jeeps is particularly significant in air-lifting operations. He also indicated that he felt GT's had some "very interesting possibilities in small sports car field, particularly in the exclusive market area."



Saturn 750-kw generator set.

"Saturn" by Solar

by R. G. Mills and P. A. Pitt*

Details of an 1100-hp high-performance gas turbine unit intended for intermittant and continuous duty in marine and land installations.

Attractive features for both marine and industrial applications are offered by the 1100-hp Saturn gas turbine. Specific fuel consumption at 1100-hp is 0.64 lb/hp-hr. Dimensions are 77-in. length, 45-in. width and 44-in. height. Weight is about 1250 pounds. Fuels include diesel, gasoline and jet types. Specification overhaul interval is 2000 hours.

This turbine has been developed by the Solar Aircraft Company under contract to the Bureau of Ships, Department of the Navy.

A study was undertaken to optimize a cycle that would produce the desired performance yet would meet the objectives of keeping over-all engine design simple, durable, and of low cost. This study, and the subsequent development program, produced the following design point data, Table 1.

Design Approach

Final layout of the engine is simple and straightforward. A sectional diagram showing the internal relation of component parts is shown. The 8-stage axial compressor, full annular combustor, and 3-stage axial turbine, are arranged with a straight-through flow path that not only minimizes flow losses but also permits a cylindrical structure of considerable rigidity and stability.

A double planetary reduction gear and output shaft are located on the turbine end. An accessory gear box with starter mounting is located behind the air inlet to shorten overall length and to make accessories accessible for servicing.

The turbine can be converted readily from a single shaft type to a two-shaft, free-power-turbine type. This feature makes the engine highly versatile.

The Saturn engine is unusually small and compact for an 1100-hp power plant. The weight-to-power ratio is approximately 1.14 lb/hp. Specific fuel consumption curve is shown.

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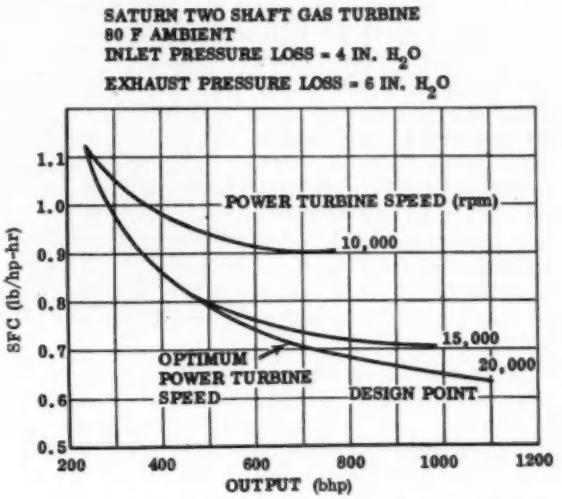
*From the paper "1100-hp Gas Turbine for Marine Applications" by the authors, Paper No. 60-GTP-11, presented at the Gas Turbine Power and Hydraulics Division Conference, ASME, Houston, Texas, March 6-9, 1960. Mr. Mills is Chief, Internal Combustion Engines and Gas Turbines, Code 645, Bureau of Ships, Dept. of the Navy, and Mr. Pitt is Chief Engineer, Turbine and Controls, Solar Aircraft Co.

Table 1 Design-Point Data

Pressure ratio	6.6:1
Compressor efficiency, %	86
Turbine efficiency, %	89
Combustor pressure loss, %	2.5
Airflow, pps	13.8
Engine speed — nominal, rpm	22300
Turbine-inlet temperature max., deg. F.	1500

Table 2 Performance Comparison At BUSHIPS and Standard Conditions

	BuShips	Standard
Maximum rating (1 hr), hp	1100	1250
Maximum rating SFC, lb/hphr	0.63	0.61
Continuous rating, hp	1020	1165
Continuous rating SFC, lb/hphr	0.64	0.63
Maximum turbine-inlet temp., deg. F	1500	1500
Continuous turbine-inlet temp. deg. F	1450	1450



Specific fuel consumption of 2-shaft turbine.

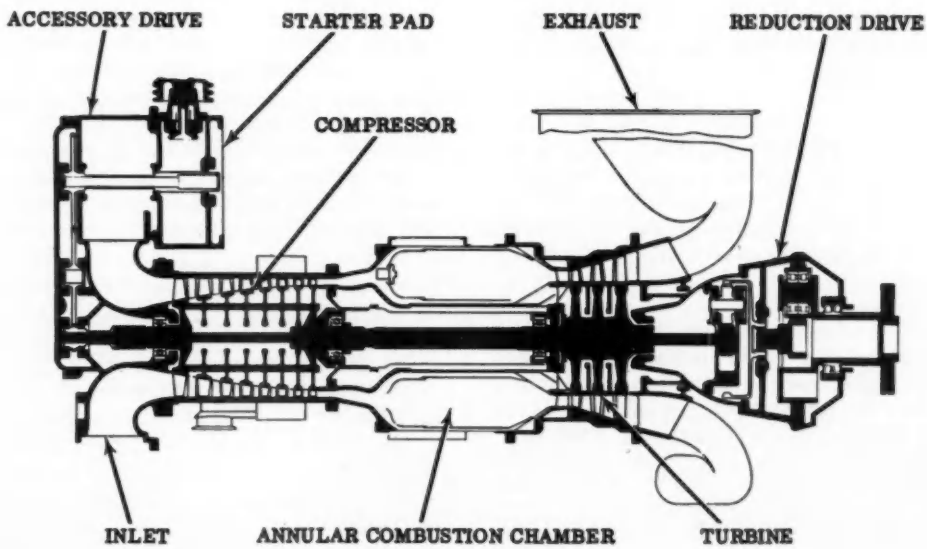
Built-In Long Life

Although initial overhaul period required by the specification is a minimum of 2000-hr, the Saturn will ultimately achieve an overhaul period several times this figure. Design life of the engine's carcass is unlimited. For rotating components—including the turbine—it is in excess of 100,000 hr at continuous rated temperature, the practical limits of available metallurgical data.

The air inlet, compressor case, compressor diffuser, turbine case, exhaust diffuser, and power-turbine bearing housing form the main structural shell of the engine. Castings are used extensively (1) where parts are unusually complicated for welded construction and (2) for additional strength. Cast parts include the compressor diffuser, turbine-inlet nozzle; second and third-stage nozzle; turbine-exhaust diffuser; power-turbine bearing support; compressor-inlet housing (which also serves as the accessory gearbox); and the main power reduction gearbox. Solar called on Cameron Iron Works for all rotating forgings.

Compressor

Compressor construction is simple and comprises five major assemblies—compressor case, stator, rotor, air inlet, and diffuser.



Cross section of single-shaft engine—drives an Allis-Chalmers 60-cycle, 450-volt, 3-phase syn-generator.

The compressor case is a rolled-sheet weldment of 17-7 PH steel with a machined bore. Provision is made for bleeding air at the fifth stage. A lateral split line was not used in order to maintain perfect roundness at all times and to allow mini-blade-tip clearance. Each stator assembly is made up of rolled strip-stock vanes furnace-brazed into punched holes in the inner and outer shroud rings.

Rotor assembly is of drum-type construction. It consists of eight rotor disks of AISI 410 steel piloted on one another and held together with a through-bolt. Hubs extend from the first and eighth-stage disks to carry the bearings and surfaces for the oil seals. Blades are cast in AISI 410 and are inserted into the rotor disks in dovetail slots.

The air inlet is a one-piece aluminum casting that takes air in radially and turns it so as to enter the first stage axially. This casting also supports the front roller bearing and accessory gearing.

Air leaving the compressor is diffused in a one-piece casting (17-4 PH steel) which also serves as a backbone of the engine. The diffuser provides support for the aft-compressor thrust bearing and, by means of a tubular extension, serves as a mount for the forward turbine roller bearing.

Turbine

Turbine construction involves four-major assemblies—turbine casing, nozzles, rotors, and turbine diffuser. The case is machined from a cylindrical forging of AISI 347 alloy. This forms a structural outer shell supporting the three turbine nozzles. Each of the three turbine-nozzle diaphragms is cast in a single piece with vanes integral with the inner and outer shroud rings. The first and second nozzle casting are made of Hastelloy C alloy while the third is cast in AISI 347 alloy.

All three turbine rotors are machined as separate disks in A-286 alloy and connected to the shaft with a throughbolt extending through from the third stage. Cast S-816 alloy is used for the first and second-stage blading while the third stage is forged of A-286 alloy. The blades are retained in the rotor rim by a conventional fir-tree mounting.

Bearings

Where the longest possible overhaul period is desired, sleeve-type bearings are generally preferable. However, rapid starting and extreme cold-weather operation of marine and military applications dictated use of anti-friction, ball and roller bearings.

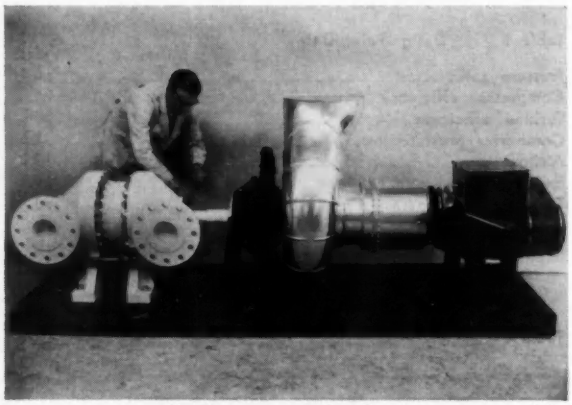
Combustor

An annular type of combustor was chosen because it offered the best solution in providing structural strength to the engine and also simplified manufacture. It also provides maximum control of radial temperature distribution to the turbine and minimum aerodynamic pressure losses.

Accessories

Main Reduction Gear—Designed to transmit 1100-hp with an input speed from the turbine of 22,300 rpm and an output speed of 1200 to 1800 rpm.

Lube Pump—Capacity of 22.5 gpm at 35 psi. A 3-element scavenge pump drains all lubrication points to the extent that the engine can operate in an attitude of up to 30-deg pitch or roll or combination of both.



Mockup of centrifugal gas compressor, left, with Saturn 1100-hp turbine engine.

Fuel-Control System—Performs these major functions:

1. Turns the fuel on or off.
2. Provides a metered schedule for acceleration to rated engine speed during start.
3. Establishes a minimum fuel flow to prevent flameout upon load removal.
4. Regulates fuel flow for constant-speed operation under load at a given throttle setting.

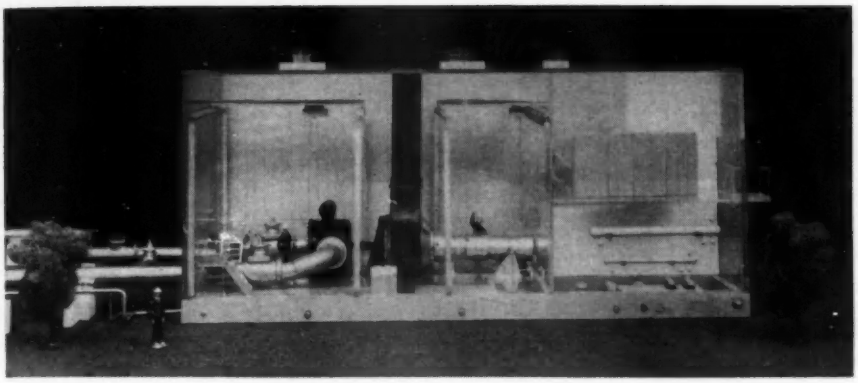
Looking Ahead

The first Saturn gas turbines to see service use are single-shaft engines used for electric-generator drive. A 600-kw set is presently being assembled for the Maritime Administration for use in a merchant ship. A similar 750-kw machine has already completed a substantial portion of a 100-hr shakedown test. Upon completion it will be disassembled, thoroughly inspected and rebuilt before being placed aboard a Navy ship to provide ship's service and emergency electrical power.

The first split-shaft engines will go to sea in a high-speed reconnaissance boat. Preliminary installation work is presently under way on the West Coast. Trial runs are scheduled for early autumn. These engines are later scheduled for installation in a large amphibious vehicle. This high-performance turbine is also especially advantageous for powering high-speed hydrofoils.

Heavy off-highway equipment also requires engines in this power range. Quick starting and superior low-speed torque characteristics of the split-shaft gas turbine—plus increase in payload that a light prime mover allows—are important advantages over the diesel engine for this use. Five of these engines are being built as prime movers for the U. S. Army "Land Train".

The oil industry has particularly demanding requirements for a combination of reliability, low maintenance, and portability in its field equipment. Two units of the present production run are scheduled for this type of service—one for pipeline pumping and one for powering portable field equipment.



Model of Columbia Gulf Transmission Company's jet-powered pumping station.

C-B RT-248-A Gas Turbine Milepost*

World's first jet unit for delivering power to a pumping station is now being built. Columbia Gulf Transmission Co. at Possum Trot, Kentucky will get this 10,500-hp unit. This company entered a testing and development program with The Cooper-Bessemer Corp. to produce and install a revolutionary gas turbine-compressor package which promises to slash cost of installing automatic unattended compressor stations by half. C-B's RT-248 gas turbine consists of a Pratt & Whitney jet engine burning natural gas as fuel, a reaction turbine developed by C-B engineers, and a C-B RF2B-30 2-stage centrifugal compressor.

Main difference between the new unit and existing gas turbine-compressors for this application lies in its ability to attain comparable efficiencies without regeneration. Air preheating is not necessary because incoming air is subjected to such high compression by the engine itself that its temperature reaches 600°F before entering the combustion chambers. Thus, thermal efficiencies obtained equal those of conventional gas turbines with regenerators.

Here, economy of the new unit for this application becomes apparent. Conventional turbine compressor packages of comparable power weigh about 255,000 lb. Bulk of their cost and weight (100 ton) is represented by the regenerator.

The J-57 weighs 3000 lb; reaction turbine weighs 17,000 lb; and compressor weighs 45,000 lb. Total: 65,000 lb or 37½ ton.

Exhaust from the J-57's combustion chambers drives three turbines. First, through a coaxial-shaft arrangement, the single-stage turbine drives the high-pressure compressor and the second and third stages, making up the second or intermediate turbine, drive the low-pressure compressor by the inner shaft. The third turbine, the reaction single-stage power turbine built by Cooper-Bessemer, couples directly to the unit's centrifugal compressor and turns it at 5000 rpm.

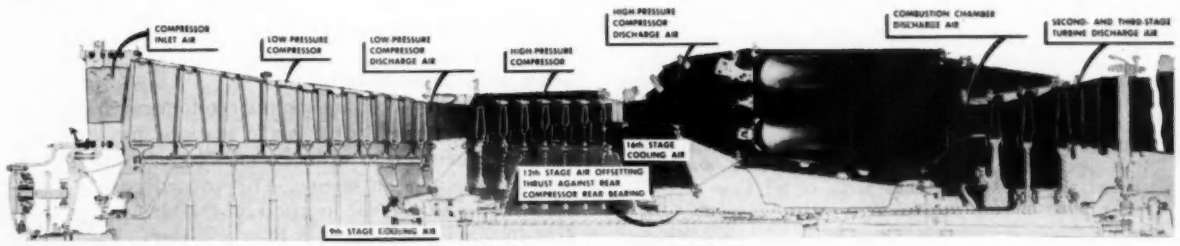
In its application to the FPC, Columbia Gulf listed these other economic advantages of the unit:

"Use of the light aircraft-type prime mover will result in smaller compressor stations and lighter station foundations.

"For major repairs and routine overhaul, it is proposed to uncouple the jet engine, substitute a temporary replacement and send the engine back to the factory. Estimated time for substitution of engine is approximately four hours, indicating a substantial saving in down-time for annual overhaul and major repairs.

"Light weight and portability of the proposed unit will make its use advantageous in remote and relatively inaccessible areas."

**"Milepost" is also the name of the Columbia Gulf Transmission Co. publication from which muchof the data for this article was taken.*


COMPRESSOR INLET AIR
LOW PRESSURE COMPRESSOR
LOW-PRESSURE COMPRESSOR DISCHARGE AIR
HIGH-PRESSURE COMPRESSOR
HIGH PRESSURE COMPRESSOR DISCHARGE AIR
COMBUSTION CHAMBER DISCHARGE AIR
SECOND- AND THIRD-STAGE TURBINE DISCHARGE AIR
16th STAGE COOLING AIR
12th STAGE AIR OFFSETTING THRUST AGAINST REAR COMPRESSOR REAR BEARING
9th STAGE BLEEDING AIR

J-57 jet engine—top half.

Planning a Vibratory Stress Determination Program

by L. D. Brown, Chief Engineer
Advanced Propulsion Division
Aerotest Labs, Inc.

Levels of rotative strain, frequency and temperature are three general items of concern to gas turbine engine manufacturers engaged in weight reduction, product improvement and general development programs. The impetus for this effort may stem from a desire to gain flight certification of the power plant in question or simply to gain knowledge of the magnitude of vibratory stresses inherent in the design.

Acquirement of technical knowledge, skills and measuring equipment to conduct such a program takes considerable time, money and experience. More important is the effort and planning required to budget accurately and forecast potential manpower, skills and resulting cost of such specialized vibratory stress qualification work.

The intent of this article is to outline briefly the planning, equipment and technique in hopes that it may assist your engineering planning group to forecast more accurately such expenditures.

Planning

Here is factual information* and experience obtained from the J-44 FAA-inhabited craft power plant certification. This information was gained as a department head, directly responsible for the test engine design, incorporated instrumentation such as slip rings, strain gages and thermocouples. Associated tools such as calibration test fixtures and test cell mounting structures for full-scale engine tests were also included in the area of responsibility.

Many skills and a wide variety of departments are directly connected with an overall vibratory stress program. To "yardstick" this effort, the following listing outlines type of skill required, duties and approximate time factors.

1. The Stress Laboratory involved has full-time concern in areas of component rig design, calibration fixtures, high-temperature test specimens, development program representation in project and design review conferences, standby on test, and preparation of reports.
2. The Project Engineer, responsible for overall results, controls expenditures, schedules test programs, and coordinates general engineering. Allocates 20% of his time over the entire program.
3. The Development Engineer, reporting directly to the Project Engineer, spends his full time from originating the design concept through to the building and testing of both components and full-scale engine.
4. The Electronics Laboratory supplies a Senior Technician for 75% of total program. He is responsible for all of the instrumentation related to such a test. Trouble-shoots during testing.
5. The Instrument Shop supplies a First Class Instrument Man for slip-ring checkout and overhaul. He is allocated full time for 75% of entire program. Pre- and post-test examination and checkout of slip rings are required.
6. The Experimental Assembly Group is required to supply a First Class Engine Assemblyman for 75% of the entire program. This man builds and disassembles the test engines fitted with slip rings and strain-gauged test equipment.
7. Test Engineering applies one man full time to writing of build, test and tear-down instructions. He also coordinates engine delivery to test cells and schedule shift operation.
8. Experimental Test supplies the necessary test crews, approximately three men for one test per month per engine over the entire program.
9. Photo Laboratory supplies necessary service for report purposes.
10. Computer Technician develops raw data to a reduced form and programs the computer as required by Project Engineering.
11. Design Engineering services the overall program, providing various stress analysis and proposals as required. Figure one-half man applied for 75% of the overall program.
12. Test Equipment Group initially supplies one Design Engineer and two Draftsmen for the design study and application of the slip ring assembly, strain gauges and lead wire routing for the test engine. Responsibility is through shakedown test of one engine. Effort is applied early in the program; figure the team full time for 25% of the program.

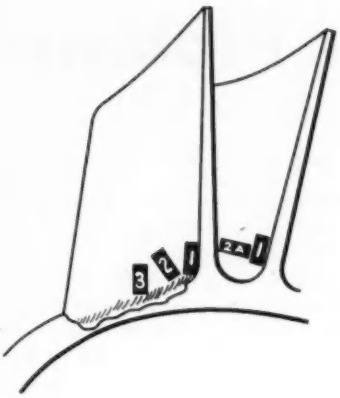
Calendar Expenditure

As defined above, such an initial vibratory stress program may entail anywhere from six months to one year's time. With the necessary experienced engineers, facilities and the instrumentation on hand, a 50% time reduction is estimated. Specialists may be contacted to assist such an effort.

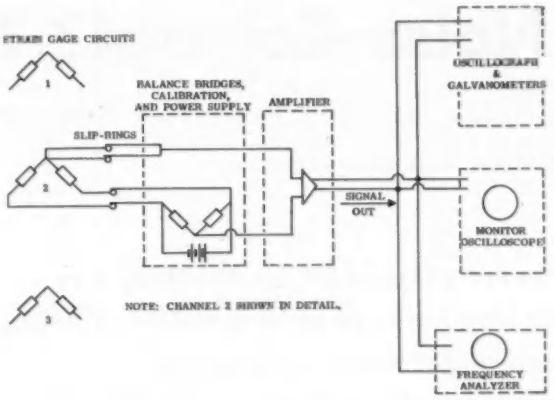
Start with Components

It is logical and certainly more economical to conduct bench tests of individual blade sections by removing, say, a segment of an inducer, rather than start pronto into a full-scale test engine. This procedure will determine, for example, the location on the blade most sensitive to vibrations, the spot that will then produce the maximum output signal from the gauges.

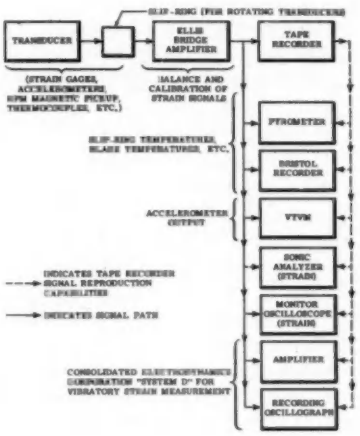
*Fairchild Engine & Airplane Corp., Report, R1316, March, 1958.



Basic instrumentation, initial.



Strain gage locations on compressor front impellar blades for dynamic tests.



Complete strain instrumentation system (one channel shown).

For instrumentation of turbine blades, strain location is generally determined by size of the available gauge and accessibility of gauge mounting areas. Because of the high-temperature conditions at the turbine, special foil-type gauges are required.

Engine Rework Next Step

A complete engine assembly set of drawings must be provided, incorporating such things as: special rifle boring of shafts; routing holes for lead wires in rotative parts; special pad and drive for the slip-ring assembly and other reworks. Dynamic and static rebalance instructions are required as compensation must be made for wires, bonding cements, and lead wires welded in place, especially where foil gauges are used. In all cases, area permitting, a bi-metallic thermocouple should be imbedded at the gauge location unless temperature-compensated gauges are used.

Gauge performance tests or determination of gauge correction factors vs temperature can be simplified into three basic steps:

Step 1 Calculation of strain on specimen
Step 2 Measurement of strain sensed by gauge
Step 3 Calculation of gauge factor

Actual gauge factor corrections have varied as much as the low of 1.95 to 2.55 in the operating temperature range of 100°F to 1500°F.

For least effect of this instrumentation on dynamic balance of the rotor assembly, 180-deg locations are used and all detail reworks are statically balanced. These are later rebalanced for as close to operating speed as possible, staying well within the original balance limits.

Instrumentation

To attain the overall objective of any stress study program, certain basic tools necessary for an investigation of this nature are: strain gauges; suitable slip-ring device; appropriate measuring and recording equipment and calibration fixtures. Many combinations of instrument readout and acquisition exist, however, the following basic equipment is necessary:

1. Multi-channel magnetic tape recorder reproduced with both AM and FM record amplifiers, as well as AM and FM reproducer amplifiers.
2. Oscillograph processor.
3. The required number of recording galvanometers.
4. Oscillograph
5. Panoramic sonic frequency spectrum analyzer, with camera.
6. Vibration shaker.

Slip Ring Pick-Up

For measurement of electrical parameters on rotating components, it is necessary to provide means of maintaining circuit continuity from the rotating to stationary assemblies. This requires use of sliding contacts such as brushes or conducting fluids. Mercury is an ideal fluid for this purpose as it can be amalgamated with copper or silver. Brushes, which are more commonly used, generally have too high a voltage drop for applications involving circuits with voltages in the low millivolt range. Improvements are being made, however, in the use of the brush-on-ring type.

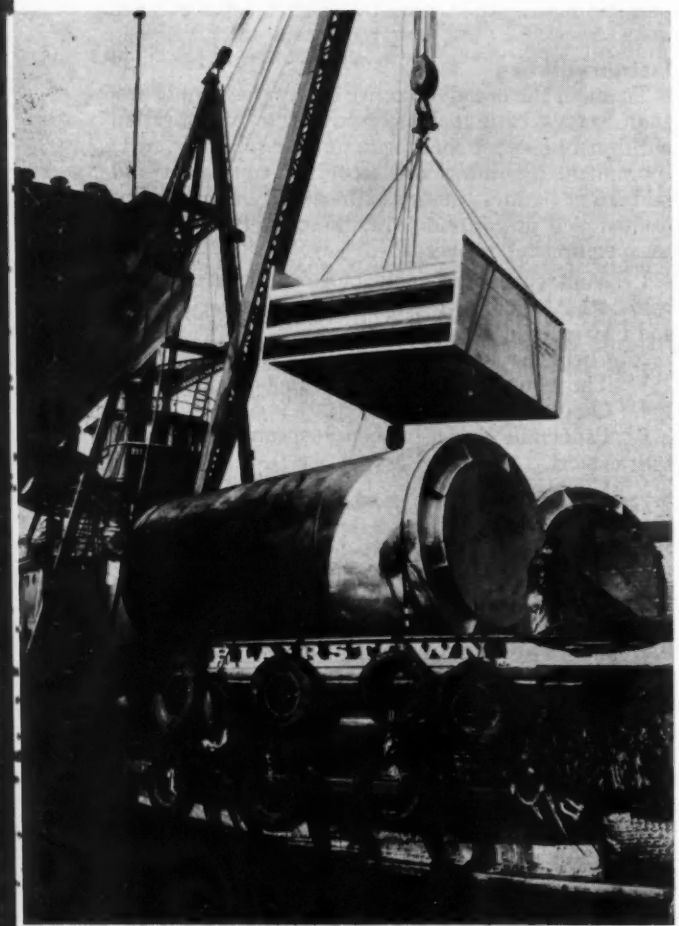
Conclusion

This brief outline only touches on skills and manpower requirements program approach and instrumentation needed for conduct of a vibratory stress determination program. As stated, its intent is to provide a guide for more realistic and accurate planning for such a test program.

Noise Control? No Major Problem

by JAMES A. MORGAN,
Chief of Project Engineering
INDUSTRIAL ACOUSTICS COMPANY

Except in aircraft application, gas turbine noise control is obtained using well-understood techniques economically and with no performance sacrifice.



Silencing principles combined with aerodynamics and structural considerations can be encorporated in various space-saving configurations. Here, cylindrical and rectangular units are loaded for overseas shipment.

Desirability of considering noise control in gas turbine applications is well known; however, magnitude of the problem involved is often exaggerated. In "other-than-aircraft" applications, requirements of noise control are seldom demanding enough to be a determining factor in evaluating gas turbines against other prime movers. This article discusses the "other-than-aircraft" noise control problem.

Noise Sources

For purposes of analysis and treatment, noise produced by a gas turbine can be considered as coming from three separate noise sources:

1 Air intake noise.
2 Exhaust noise.
3 Noise radiated from casings and ducts.

Air intake noise is characterized by a high-pitched "scream", the frequency of which is determined by the compressor blade passing frequency. In some marginal situations, reduction of this peak noise may be sufficient. Generally, however, suitable noise control requires reduction of intake noise at all frequencies from 37 to 9600 cycles per second.

Gas turbine exhaust noise is usually thought of as a low-pitched rumble. This source is the predominant one at low frequencies. However, it should be noted that high-frequency noise from the exhaust may approach that of the intake. High-frequency components of exhaust noise are sometimes overlooked since observers close to the source are not apt to place themselves in line with the hot exhaust where high frequency components are directed.

Noise radiated from casings and ductwork is usually of no importance in controlling neighborhood noise if the gas turbine is housed or properly jacketed.

Criteria

The two general types of noise control criteria are (1) those designed to protect operating personnel from hearing loss or discomfort, and (2) those designed to avoid unfavorable public relations in the areas neighboring the noise source. In order to obtain satisfactory and economical noise control, a criterion should establish the maximum Sound Pressure Level tolerable at the critical location for each of the octave bands.

Assistance in choosing suitable criteria can be obtained from gas turbine manufacturers or from technically-qualified manufacturers of noise control equipment. In very large installations, it may prove economically sound to engage an acoustical consultant.

Noise control equipment can be readily applied to effect the desired amount of intake or exhaust noise control. Intake or exhaust silencers may be fabricated to form an acoustically-treated portion of the duct; they may take the form of an exhaust stack; or they may be built into special space-saving configurations. Noise

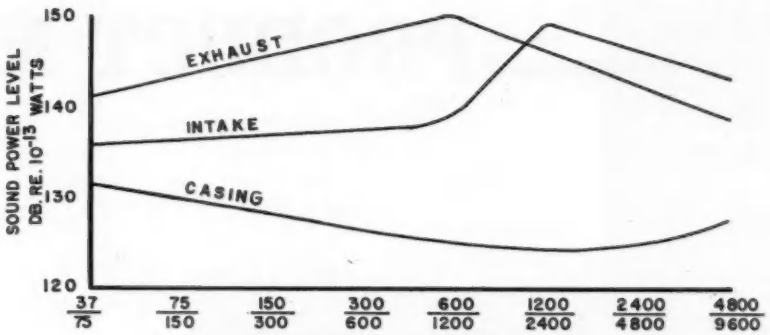


FIGURE 1

Intake, exhaust and casing Sound Power Level (PWL) spectra emitted from source in all directions from some fairly representative large simple cycle gas turbines now in operation. The more familiar Sound Pressure Level (SPL) measured at a particular location would be much lower.

control equipment manufacturers can design and furnish silencers, or in some cases apply standard designs, suitable to any practical requirement.

Silencer Design Considerations

Noise control would be an easy problem indeed, if acoustical requirements were the only design parameters of interest. While the acoustical requirement must be established carefully, aerodynamic, structural, and equipment arrangement factors are also of prime importance in a good gas turbine silencer design.

Importance of aerodynamic design is obvious when one considers that the useful power capability of a simple-cycle gas turbine will be decreased by over 2% for a 4-in. H_2O intake pressure drop or over 1% for a 4-in. H_2O exhaust pressure drop. Economical pressure drop specifications usually range from 0.5-in to 1-in. H_2O for exhaust silencers. By utilizing suitable baffles and other acoustical arrangements, these low pressure drops can be obtained in a compact, economical silencer.

Conclusion

It is hoped that this short discussion of gas turbine noise control will dispel the idea, wherever it may still linger, that this problem should be a major consideration in evaluating desirability of the gas turbine for any application. Although noise is a gas turbine problem which cannot be ignored, its solution does not make it a dominant cost factor even in rather critical locations.

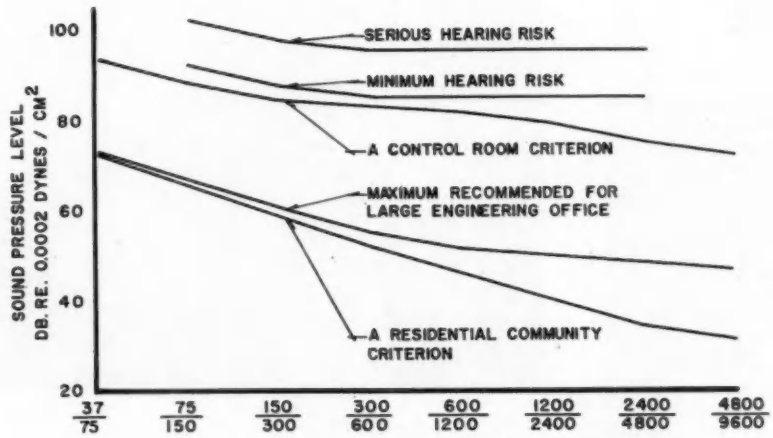


FIGURE 2

Illustrates noise control applications in general but not for specific application.

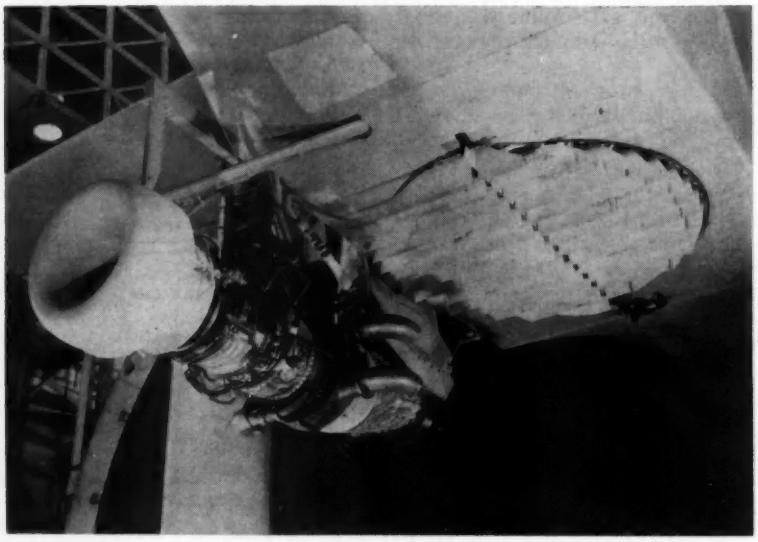
GT PRODUCT NEWS

Navy's Newest Ground Support equipment is demonstrated at Glenview Naval Air Station, Illinois. Versatile new low-silhouette TD-80 Hough tractor mounts an AiResearch small gas turbine, marked by exhaust port. That's the Navy's A3J all-weather 2-place, 25-ton Vigilante jet bomber poking its nose into the picture.

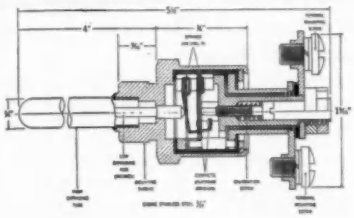
110

GE's J85 Powers Lift Fan . . . In NASA's 40-ft by 80-ft wind tunnel, GE's lift fan is driven by a J85 turbojet mounted under fuselage of full-scale test model. Fan (right center) multiplies forward thrust 2500-lb to produce downward thrust of 7500-lb for vertical takeoff and landing maneuvers.

111



MORE NEW PRODUCTS FOLLOW ►



Inlet-Exhaust Temperature Control Switch

Control Product's new switch is constructed of all high temperature alloys and has a calibration range of −20°F. to 1750°F. with safe momentary overshoot to 2000°F. It is used for gas turbine inlet and exhaust temperature regulation, heat exchangers and oil in gear reduction boxes. You'll be surprised to see what this company has to offer in this and many other control devices.

112

Use your GT Reader Service Card.

Automatic Clutch Protects Turbine Components

Salsbury Corporation is producing an automatic centrifugal friction clutch which accomplishes the following functions on gas turbine installations:

1. Delays application of any load up to approximately 75% operation speed, allowing turbine to be accelerated without load until an efficient speed is reached.

2. Applies load gradually and smoothly after turbine has reached an efficient speed, preventing shock to load and turbine components.

3. Limits sudden overloads that might occur, protecting transmission and turbine components.

Salsbury's automatic clutch has inherent design features that make it ideally suited for gas turbine installations. Simplicity in design, flexibility in contour to conform to established space envelopes . . . symmetry in design of components to assure dynamic balance and its adaptability to the use of lightweight materials all contribute to its desirability for gas turbine applications. These design features and performance characteristics can best be illustrated by the following case history of a typical gas turbine development project:

Design Requirements:

A. Maximum clutch drag below 4000-rpm, 1-in. lb.

B. Polar moment of inertia of driven mass to be accelerated= 0.5# in.sec^2.

C. Number of cycles useful life of clutch = 5000.

D. Time of acceleration per load cycle from max. to zero slip = 1. sec. min. 5-sec. max.

E. Dry clutch.

F. Complete release at 4200-rpm.

G. Torque transmission @6000-rpm — 180-lb. ft.

113

New Portable Oil Filtration Unit

This low cost filtration unit provides a quick means of accomplishing extremely high oil filtration. The new oil filter unit is available from the Kidde Aero-Space Division, Walter Kidde & Company, Inc. It is capable of providing 0.5 or 3.0 micron filtration; a change from one filtration level to another is accomplished by replacing the filter element and resetting a panel valve.

Operation is automatic once the starting switch is moved to "On" position. Oil may be pumped from an external source, filtered and stored in the 20 gallon internal reservoir or returned to the original source. Oil may be pumped from the internal reservoir, filtered and directed to an external destination or continuously filtered internally. The panel is 3′ x 3′ x 2′ deep, has 5 filters, electric motor and pump, controls, instruments, and all on wheels.

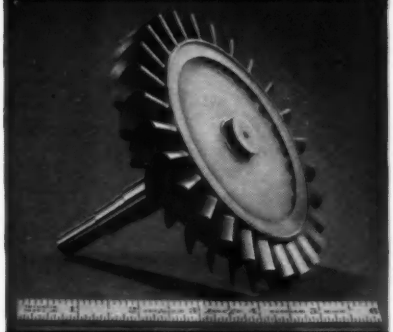
114

New Tape Assures Leakage Detection

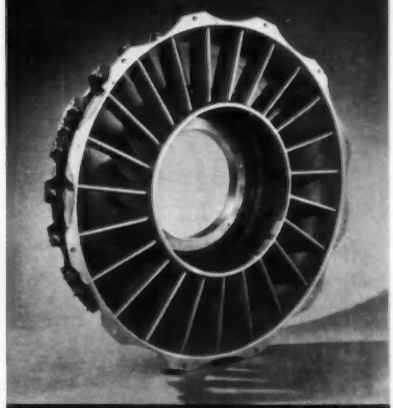
Gas and liquid leakage of a little as 1/100 cc per hour can be detected instantly and simply with Tec-Tape, a flexible, adhesive-backed tape bearing indicators which turn a stated contrasting color on exposure to a specific gas or liquid. Offered by Pyrodyne, Inc., manufacturers of Temp-Plates and Temp-Tapes and now Tec-Tape.

115

STALKER WELCOMES CHALLENGING ASSIGNMENTS



in BRAZED, STAINLESS STEEL or SUPER ALLOY, SHEET METAL FABRICATIONS



We are equipped to engineer, develop, as well as produce strong, weight-saving assemblies. We have complete facilities for machining, for high temperature brazing* as well as for heat treat, annealing and stress relieving — complete inspection and testing. WORK EXPERIENCE ON THE MOST INTRICATE, PRECISION ASSIGNMENTS. Prototype and/or production orders. Call or write for specific information.

*Up to 48" in dia.

THE STALKER CORPORATION
905 Woodside
Essexville 1, Michigan
Phone: Bay City, TWinbrook 3-7562

For more information write in No. 98

PRODUCT NEWS . . .

New Filter Housing From Micro Metallic

Special features of a new filter housing by Micro Metallic Division of Pall Corporation include a straight-thru design. This feature permits the bowl to be removed from the pipe line without disturbing the pipe connections. Container design permits fabrication in a wide variety of materials with maximum cleaning ease and accessibility to all fluid passageways. Housing is generally furnished in type 304 stainless steel. Housings can be designed to withstand up to 10,000-psi; 125 or 300-psig is standard. Filtration ratings of elements range from 2 to 55 microns nominal (98%) with absolute ratings as low as 15 microns available with certain types of elements.

116

Delavan
Fuel Injectors

GO WITH GAS TURBINES EVERYWHERE

■ Many Delavan fuel injectors are developed specially for new or unique engines: experimental gas turbine automobile engines, for example. Requirements often involve a high degree of reliability for long periods of time, as in locomotive and marine fuel injectors developed by Delavan.

■ When you are considering a new or difficult fuel injection application be sure to consult with us. A Delavan designed and manufactured injector may well reduce costs, save you valuable time or improve the performance of your equipment.

■ Delavan can bring a fund of developmental experience and specialized manufacturing ability to your fuel injection problems . . . ability that is unparalleled in the industry. Delavan is the world's largest manufacturer devoted to the design and manufacture of fuel injectors and spray nozzles.

■ *If an exacting fuel injector for gas turbines is needed . . . so is Delavan. For information write:*

DELAVAN Manufacturing Company
WEST DES MOINES, IOWA

For more information write in No. 99

New Long-Life Governor From AiResearch

Extreme design simplicity is the feature of a new pneumatic governor developed by The Garrett Corporation's AiResearch Manufacturing Division, Phoenix, Arizona.

Problems limiting the life of most governors have been solved by the elimination of seals, bearings and flyweights giving long accurate life with very low hysteresis.

Now warranted for 3000 trouble-free hours between overhaul, an ultimate 10,000 hour overhaul life for the AiResearch unit is predicted.

117

Convairs Independent Of Ground Support

A unique "stinger" power system, designed to make Convair aircraft with Napier or Allison propjet engines completely independent of ground support equipment, has been announced by The Garrett Corporation's AiResearch Aviation Service Division. Hub of the installation is an AiResearch gas turbine mounted in the airplane's tail cone,—the "stinger" area—which has been depressurized. System has design flexibility to meet specific requirements of each individual aircraft. It can provide pneumatic power, electrical power, or various combinations of both.

118

New Improved Cobalt-Base High-Tungsten Superalloy

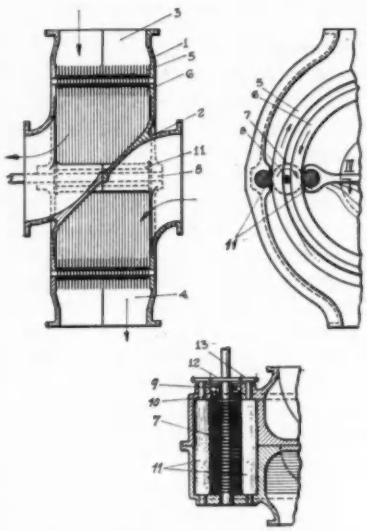
A newly improved WI-52 cobalt-base high-tungsten superalloy that possesses greatly improved high temperature strength in the 1800°F range with good ductibility and corrosion resistence is now commercially available in both shot and ingot form from WaiMet Alloys Company. This air-melted superalloy has excellent castability and foundry characteristics. Its primary use has been for investment-cast aircraft gas turbine parts such as vanes and blades.

119

Use your GT Reader Service Card.

GT PATENTS

By J. W. Sawyer



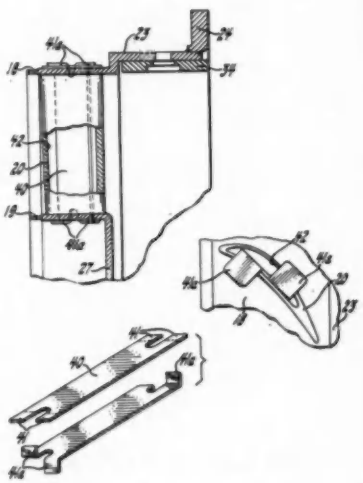
REGENERATIVE HEAT EXCHANGER WITH MOVEABLE MATRIX (2,932,492) 12 CLAIMS Gunther Lange, Germany, assignor to BMW Triebwerkbau Gesellschraft mit beschraenkter Haftung. This exchanger consists of a matrix composed of two concentrically arranged stacks of annular plates (5 and 6). These plates rotate in opposite directions. They are forced into scaling engagement with spacing discs. A housing (1) is sub-divided into air space (3) and gas space (4) by separating wall (2). Rotating matrix consists of two concentrically arranged stacks (5 and 6) of annular thin plates. Spacing discs (7) on shafts (8) are arranged in the plane of separation between air space (3) and gas space (4). These spacers are between the two stacks (5 and 6) and are placed to fill the spaces between individual adjacent matrix discs for their entire radial depth. Discs (7) and individual plates of 5 and 6 are kept under resilient pressure by springs (9) and thrust members (10). This ensures air-tight sealing of the gas spaces. Cylindrical rollers (11) serve to guide the stacks of discs (5 and 6) and also seal the inner and outer peripheral surfaces of the stacks. At least one guiding member is resiliently mounted to compensate for thermal expansion of discs.

MIXING VALVE FOR GAS TURBINE COMPRESSOR (2,932,452) 5 CLAIMS Wilton E. Parker, Encino, and Alexander Silver, Tarzana, Calif., assignors to The Garrett Corporation, Los Angeles, Calif., a corporation of California. A valve and system for mixing hot and relatively cool fluids bled from a gas turbine compressor permits alternate supply of either mixed compressed air or uncontaminated breathable air through the same conduit.

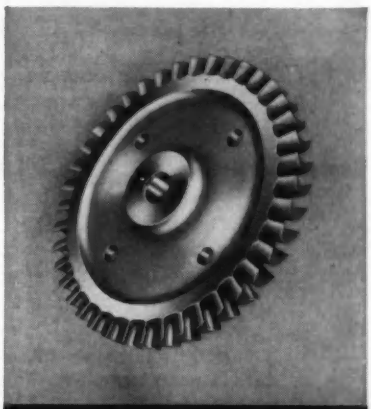
TANGENTIAL BEARING SUPPORTS (2,936,999) 5 CLAIMS Richard J. Coar, West Hartford, and William W. Jacobus, Columbia, Conn., assignors to United Aircraft Corporation, East Hartford, Conn.

REGENERATIVE HEAT EXCHANGER, SPECIFICALLY AIR PREHEATER (2,936,160) 20 CLAIMS Hans Robert Nilsson, Ektorp, and Walther Per Sigvard Persson, Johanneshov, Sweden, assignors, by mesne assignments, to Svenska Rotor Maskiner Aktiebolag, Nacka, Sweden.

BYPASS GAS TURBINE POWER PLANT EMPLOYING REGENERATIVE CYCLE (2,930,190) 5 CLAIMS John D. Rodgers, Prairie Village, Kansas, assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania. Provides an improved regenerative type plant with minimum ducting.

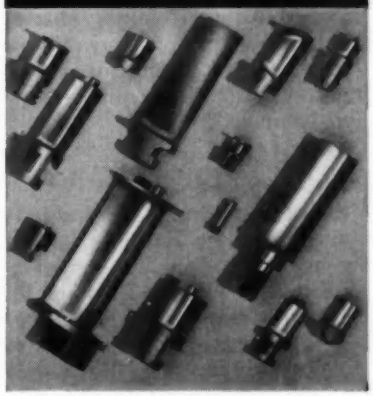


TURBINE NOZZLES (2,925,998) 14 CLAIMS John R. Hayes and Stephen C. Lampman, Indianapolis, Indiana, assignors to General Motors Corporation, Detroit, Michigan, a corporation of Delaware. Nozzles and shroud rings, described, are continuous and nozzle vanes are mounted in both shroud rings so they are free to slide and permit expansion. Vanes (20) are hollow and are held in position by retainers (40). Retainer is a metal strip notched to provide two tabs (41) at each end. The key is flat prior to assembly so it may be passed through central opening (42) in nozzle vane. When nozzle vane and retainer strip are in place in the shrouds (18 and 19), tabs at each end are bent in opposite directions so tabs (41a) provide a head on each end to prevent vane from sliding out of either shroud.



• wheels
• blades
• buckets

Schellens-True Corp.



The Schellens-True organization is devoted exclusively to the manufacture of turbine blades, wheels, vanes and nozzles of all types, machined from a wide variety of alloys and materials. We have developed entirely special automatic blade and wheel machining equipment available nowhere else. Creative engineering, precision manufacturing and rigid quality control assure a reliable product at a minimum cost.

May we quote on your requirements?

SCHELLENS-TRUE CORP.
Ivoryton Connecticut

1ST30

For more information write in No. 100

GT PRODUCT TECHNICAL FILE

Seals Are Issue Here

"Scotseal" is described in detail in a new Chicago-Rawhide bulletin. It is a "self contained omni-purpose type seal", used primarily as an oil seal. Another bulletin (not quite so new, but just as important), describes Chicago-Rawhide's metal bellows seal for pressures up to 500-psi and temperatures over 1000° F. Both are good bulletins for gas turbine men.

120

Latest Info On Gear Honing

A new 4-page, two-color profusely illustrated brochure (H60-6) entitled "Newest Developments in Gear Honing" is now available from National Broach & Machine Company. Described and illustrated in the brochure are the honing principle and a new machine called the Red Ring Model GHD Gear Honing Machine. A comprehensive table listing production data for present industry gear tooth honing applications is included.

121

Multi-Purpose V-Band Couplings

A new 4-page brochure is now available with complete design information on V-Band Couplings for connecting and sealing all types of tubing, piping, ducts, containers or structural devices for both aircraft or industrial applications by Marman, a division of Aeroquip Corporation.

122

GE's Versatile Turbojet

"J85 Turbojet" . . . . Bulletin GED-4095, 12 pages, is a new illustrated basic descriptive bulletin covering General Electric's lightweight, high performance J85 turbojet. In addition to engine specifications, performance data, dimensions and an up-to-date review of flight-testing and applications, a special section is included outlining the J85's suitability as powerplant for STOL and VTOL aircraft including helicopters.

123

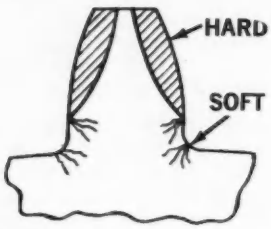


Figure 3
Typical flame hardened gear tooth showing stress concentrations at localized hardened area and soft fillet

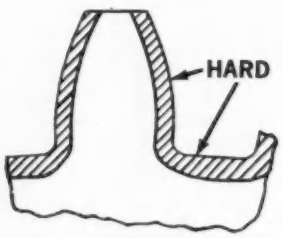


Figure 4
Philadelphia induction hardened gear tooth showing full contour hardened area

"Full Tooth Contour Hardening Of Large Gears"

That's the title of an interesting new booklet now being offered by the Philadelphia Gear Corporation. Fully describes their new method of hardening large gears. Advantages of this new method are given in detail.

124

Quiet, please! Lord Products Guide Tells HOW

Eight illustrated pages tells just how to select the right bonded rubber mounting or flexible mounting system tailor-made for such industries as truck, automotive, marine, construction equipment, ground support equipment, rail roads, missile, electrical, etc.

Lord Manufacturing, producer of vibration, shock and noise control equipment, lists the whole story in Bulletin #905, the "Lord Product Guide." Notes are made of other available Lord literature, too. This well illustrated booklet includes general design, application and performance data for 22 product series.

125

Continental's Turbomeca Artouste

Continental has issued a single sheet loaded with data on this small 400-hp single shaft unit with output shaft geared for 6000-rpm.

126

"Mighty Midget"— New 10-Page Brochure

AiResearch's mighty midget, the 30-shaft-hp gas turbine—GT P 30-1—is beautifully illustrated and fully described in a handsome new 10-page brochure from the Garrett Corporation.

127

Olsen-Rava Balancing Machine

"Tinius Talks about Olsen-Rava Electro-Dynamic Balancing Machines" is the title of an informative 8-page bulletin just released by the Tinius Olsen Testing Machine Company.

Two lines of balancing machines covering a wide range of gas turbine applications are described. These include the Type S for small parts from 1 oz. to 22 lbs. and the Type D for heavier parts to 66,000 lbs. or more.

128

Electronic Instruments Described

Well illustrated brochure published by the Liquidometer Corp. describes the electronic and electromechanical instrument systems applicable for marine and industrial equipment among others.

Typical products represented include wide range of precision equipment, both electronic and electromechanical.

Examples of the products and services are offered 'midst a wealth of pictures including views of the Liquidometer plants and facilities.

129

Use your GT Reader Service Card.

INDUSTRY NEWS . . .

(Continued from page 13)

Overhaul-Life Upped From 200 to 1000-hr

Successful 2000-hr run of an AiResearch GTU multi-purpose small gas turbine engine has just been completed. Test is believed to establish a new record for auxiliary power units of this class. Recent design and material advances incorporated in the unit were proved out during the test. As a result, overhaul-life has been dramatically extended from 200 to 1000-hr. Unit tested is an AiResearch universal gas turbine (GTU85-3) built as auxiliary power equipment for use aboard giant Douglas C-133 turboprop transports.

Continental-Turbomeca Turbine Contract Extended

The ten-year license agreement between Continental Motors Corp. and Turbomeca, S.A., of Bordes, France, for the exclusive sale and production of Turbomeca turbines in the U.S.A., has been extended, C. J. Reese, Continental Motors president, has announced. These turbines are produced by Continental's subsidiary, Continental Aviation and Engineering Corp., of Detroit, Mich., and Toledo, Ohio.

Under the agreement, a much closer coordination will be possible as Continental will provide complete sales and service in the U.S.A. and, conversely, Turbomeca will provide the same services for both companies in Europe. In other territories, the two companies will provide united services as required.

Mach 2 Airliner In The Works

Dassault, private aircraft enterprise which produces, among others, the advanced Mirage IV fighter, and Sud-Aviation, the state corporation which perhaps is best known for its Caravelle commercial airliner, have signed a working agreement which will tend to concentrate the development and industrial facilities of these French companies. Priority in the new joint operation is development and construction of a medium-range supersonic airliner to be known as the Sud-Dassault Super-Caravelle.

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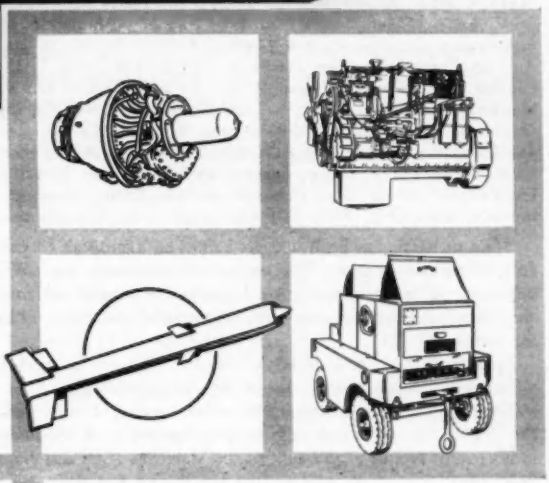

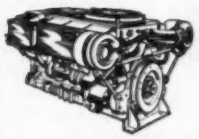

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GT TECHNICAL BRIEFS

Turbofan—The Transport Engine A review of three papers presented at the 1960 SAE National Aeronautical Meeting, New York. 172A, "The Turbofan Engine and Its Application Versatility" (A) by S. M. Taylor, Chief, Commercial Sales and C. B. Brame Airplane Performance Engineer, Pratt & Whitney Aircraft, Division of United Aircraft Corporation, East Hartford, Connecticut; 172B, "Aft-Fan Engines for Commercial Transport" (B) by B. J. Gordon and R. C. Hawkins, Flight Propulsion Division, General Electric Company, Cincinnati, Ohio; 172C, "Turbofan and By-pass Type Engines for Jet Transports" (C) by A. A. Lombard, Director of Engineering, Rolls-Royce Limited, Derby, England and D. Gerdan, Director of Engineering, Allison Div., General Motors Corp., Indianapolis, Indiana. Letter (A), (B) or (C) after each quote indicates source.

"The turbofan has been accepted as 'The Transport Engine'." (A). "Turbofan engines that engine manufacturers are offering differ in rather basic ways. Mechanical arrangement differences are rather basic, but of even more importance, the cycles utilized are different." (B)

Apparently Sir Frank Whittle had the idea of the turbofan. "There was a remarkable degree of foresight displayed in all Whittle patents but perhaps the most significant was that of the ducted-fan or by-pass engine, basic principle of which were in his patent No. 471, 368 applied for March 4, 1936 and granted September, 1957." (C) "The first fan engine was designed and built by Metropolitan Vickers; it was on test in 1946 (see cover). This background has been mentioned to offset the general impression that the fan engine is new." (C) Obviously the fan engine is more complicated than the jet, the reason for its delay in development. Figure 10 of (C) shows the two basic designs. The aft-fan is preferred by (B) and the by-pass system by both (A) and (C).

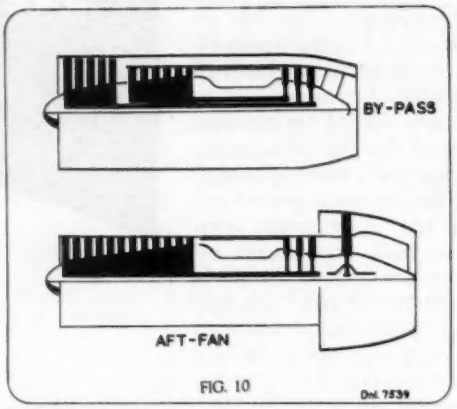


Fig. 10 of (C)

"Relatively early in this fan engine era, General Electric had front-fan engine experience, and as a result of the bypass ratios that would eventually be required for maximum performance, a new approach had to be adopted. Result of this decision was the CJ805-23 aft-fan engine. Included among its many advantages are solutions to all three major problem areas encountered on the front fan: aerodynamic design; mechanical design, growing flexibility; and of special important in commercial applications, acoustic noise. Simplicity of the aft-fan concept is apparent." (B) Comparison details of this turbofan with the CJ-805-3 jet are given on page 12, GAS TURBINE, May-June, 1960.

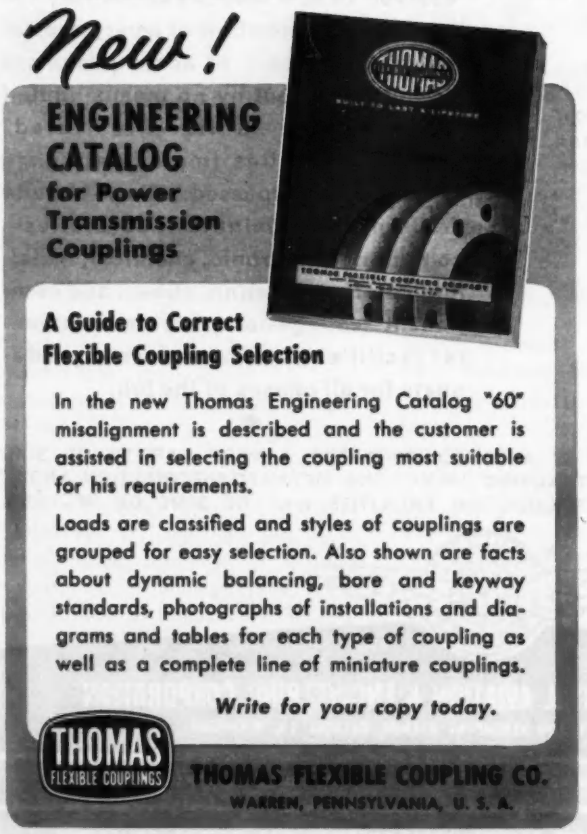
"It is appropriate here to examine briefly the performance differences between a turbofan as we have conceived one and a turbojet. Fortunately, this can easily be done by comparing our JT3C-7 turbojet engine to our JT3D-1 turbofan engine since the JT3D-1 engine was conceived by adding two fan stages to the JT3C-7 in lieu of three compressor stages and by adding another turbine stage to furnish the added power. Fig. 2 shows a comparison of the characteristics of the engines." (A)

Fig. 2 of (A)

Take-Off Sea Level Static	JT3C-7	JT3D-1
Thrust—Lb	12,000	17,000
TSFC—Lb Hr Lb	.785	.520
Airflow—Lb Sec	185	450
By-Pass Ratio	0	1.45
Over-All Pressure Ratio	13	13
Fan Pressure Ratio	0	1.7
Basic Diameter—In.	39	53
Comparable Lengths—In.	122.4	129.1
Weight—Lb	3,495	4,025
Relative Price	1.0	1.3

"Rolls-Royce interest in by-pass engines was generated by an Air Ministry requirement for what are now termed 'V' bombers in the B.35/46 specification, as long ago as 1946 . . . It was recognized at around that time that these conditions would be eminently suitable for commercial jet transport operation.

"With such a promising field ahead and at that time with the thought that 0.87 Mach No. was about the practical limit for long-range jet operation, a considerable amount of effort was devoted to study the optimum propulsion system. The first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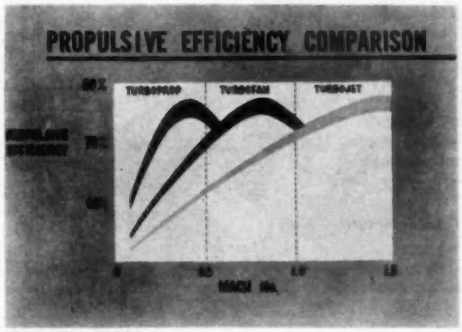

Fig. 2 of (B)

practical project proposal was the BJ.80 engine (of 0.6 by-pass ratio) of 8000 lbt, dated February, 1947. Design of the first Conway engine commenced in January, 1950 and it first ran in August, 1952 . . . Since that date, considerable work has been devoted towards developing the Conway engine. It has, of course, changed materially during this time (having increased from 9000 lbt in 1952 to 20,000 lbt in 1960) . . . . In November of last year, development running of the RB.141 engine commenced. It is the basis of a new family of by-pass engines. In October this year a further version, the RB.163, will be on test." (C)

All three papers have the same conclusion—use the turbofan for transport service, for slower planes requiring a better fuel consumption. Fig. 2 of (B) shows why. Comparing figures of the GE aft-fan unit CJ-805-23 to the P & W by-pass unit JT3D-1, we find they both have about the same fuel consumption and weight ratio. In other words, there are two ways to accomplish the same objective—a better jet unit at speeds below 0.85 Mach No.

Gas Turbine Cycles and Design Concepts for Vehicle Propulsion by C. H. Paul, Assistant Chief Engineer and E. L. Klumm, Engineering Specialist, AiResearch Manufacturing Co. of Arizona, Div. of Garrett Corporation, Phoenix, Arizona. (No. 212C, SAE National West Coast Meeting, August 16-19, 1960)

This is an unusually fine paper which shows that AiResearch is in a position to furnish gas turbines designed for propelling vehicles. The conclusion states ". . . . a whole new horizon of gas turbine applications is in view . . . ."

An Advanced Automotive Gas Turbine Engine Concept by I. M. Swatman & D. A. Melohn, Ford Motor Company. (No. 187A, SAE Summer Meeting, Edgewater Beach Hotel, Chicago, Ill., June 5-10, 1960)

A review of the 11 cycles investigated by Ford is first given. The paper concludes "The engine described as Cycle 11 is now under development at Ford Motor Company. Despite what may be considered as adding complexity to an engine originally herald-

(*Continued on page 42*)

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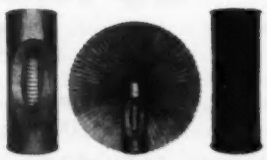

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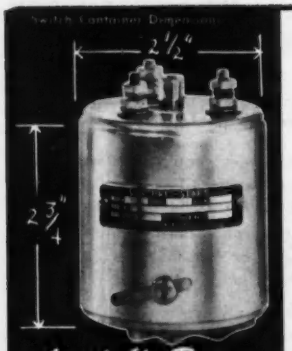

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TECHNICAL BRIEFS . . . (Continued from page 41)

ed as only having two moving parts, the mechanical design turned out surprisingly compact. Mechanical reliability at the present stage of development has surpassed expectation and with the weight. little more than two pounds per horsepower, a particularly attractive heavy-truck engine contender appears to be developing."

Problems Associated with Water-Contaminated Jet Fuels by Henry W. Schab, Senior Project Engineer in Fuels Branch, Fuels and Lubricants Div., U. S. Naval Engineering Experiment Station, Annapolis, Maryland. (Published in Journal of the American Society of Naval Engineers, February, 1960)

"Purpose of this paper was to present the existing problems and to review the avenues of approach being followed to their solution. The final and complete answer is not yet available but interim solutions are being developed and evaluated in and outside of the military services. From the manufacture of these fuels to the final handling at the jet aircraft (or missile) utmost care must be taken by all hands to prevent contamination."

Anyone interested in this subject should certainly obtain a copy of this valuable paper.

Operational Experience With a 15-MW Gas Turbine Generator in an Iron and Steel Works by F. K. Konig, Managing Director, Huttenwerk, Rheinhausen, A. G. Rheinhausen, Germany. (No. 60-GTP-16, ASME, Gas Turbine Conference, Houston, Tex., March 6-9, 1960)

The author states the basic philosophy for the installation of gas turbines burning blast-furnace gas in the power-generating systems of an iron and steel works. A description is given of the two gas-turbine generators (Brown Boveri) at the Huttenwerk Rheinhausen, A. G. and their operating experience. The author states in his conclusion "To sum up, it can be said that the machine has suffered from comparatively few 'teething' troubles and that during the course of the year it has given very good results. We are of the opinion that this machine and the one recently put in service will eventually measure up fully to our hopes for them in regard to both economy and durability."

Description of a 9000-HP Single Shaft Gas Turbine by O. C. Schoeppner, Assistant Manager, Gas Turbine Department, Clark Brothers Company, Olean, N. Y. (No. 60-GTP-18, ASME, Gas Turbine Power Division Conference, Houston, Texas, March 6-9, 1960)

The recognized need for simplicity together with reliability has been the main consideration in the design of the unit discussed in this paper. At present, an intensive test program is under way and it is expected that the new Clark gas turbine will soon be ready for installation.

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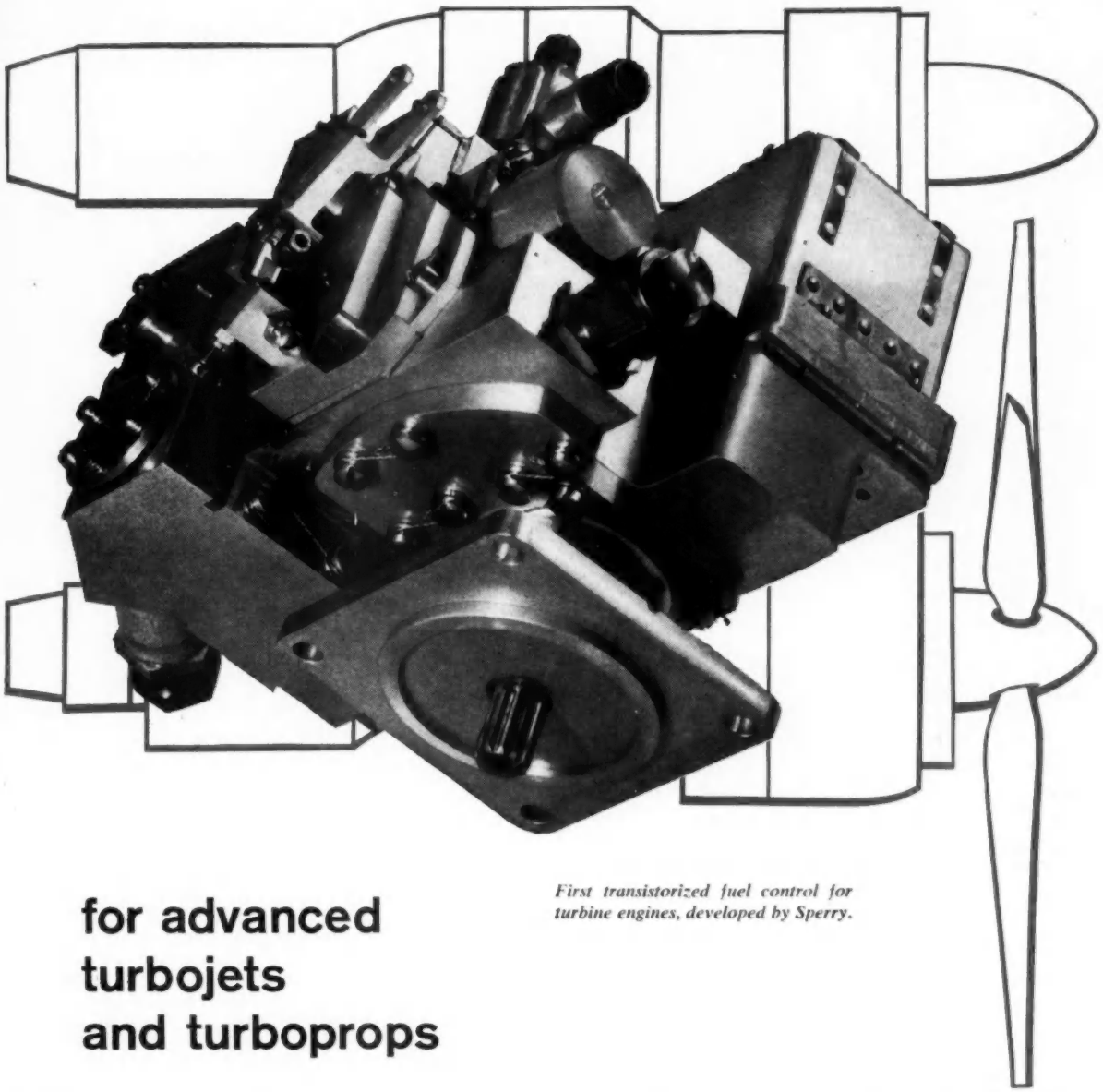

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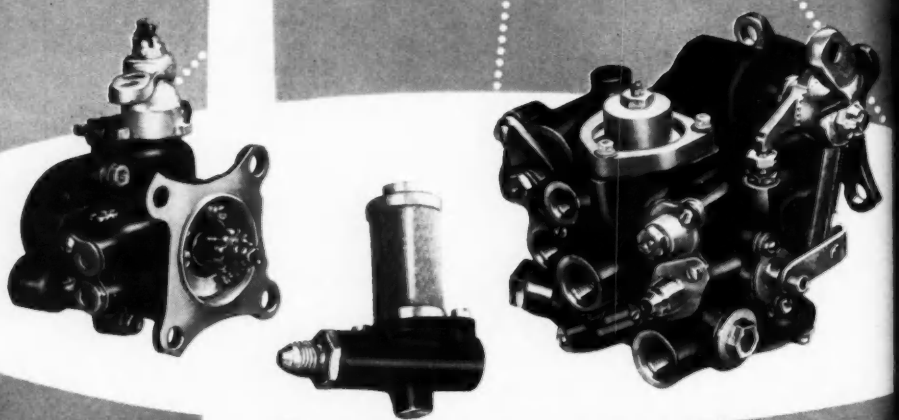

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